

# MD-2

***Dual Stepper Motor System***  
**PC-Based Automation Made Simple**

## User's Guide

Revision E

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Please see page 1-35 for warranty information.



# ***Sections***

## **Section 1 - *The MD-2 System***

Installation and operation of the MD-2 dual stepper motor control system. Information on features of the MD-2 hardware and discussion of technical subjects.

## **Section 2 - *The MD-2 Program***

Installation and use of the MD-2 program which allows the operator to control up to 6 motors (3 MD-2 systems) using the keyboard or joystick. All motor parameters can be edited and experimented with. Motion control programs can be created automatically and executed from the environment, from batch files, or from the command line.

## **Section 3 - *Level 1 Subroutine Library***

Information about using the level 1 subroutine library to create simple custom motion control programs in BASIC, Q-Basic, Quick-Basic, Visual-Basic, Pascal and C languages.

## **Section 4 - *Level 2 Subroutine Library***

Information about using the level 2 subroutine library to create complex custom motion control programs in Quick-Basic, Visual-Basic and C languages. features include ramping, linear and circular interpolation, backlash compensation and more.

## Section 1

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# ***The MD-2 System***

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# Section 1

## The MD-2 System

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# Introduction

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Congratulations for purchasing the MD-2 Dual Stepper Motor System. This package will provide all of the components necessary to operate stepper motors from an IBM style personal computer including electronics, power supply, motors, cables, software and documentation. Even though this guide covers all MD-2 products, the term 'MD-2' will be used to refer to all models. Any differences between the models will be pointed out when necessary. The MD-2 system is very easy to install and operate as you will find out shortly.

If you have the time and are new to motion control, we suggest you read this entire section to learn the various terms and concepts associated with this subject, then go to the section describing the MD-2 program. If you are already familiar with motion control and your time is limited, we suggest you read through this section until you get to the discussion of parallel printer ports, then go directly to the MD-2 program section to begin operating the system. If your application requires a custom program, you can then select the level 1 or level 2 subroutine libraries and read the appropriate section.

# System Requirements

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The following computer components are required to use the MD-2 system as intended:

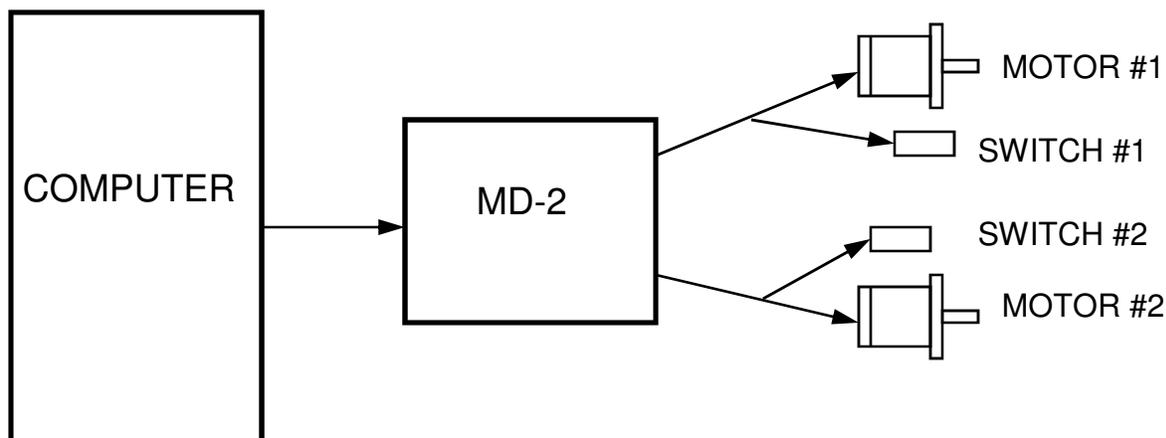
IBM style personal computer (PC, AT, 386 or 486), 286 or higher recommended.

640K of system memory or more.

5.25" (1.2m) or 3.5" (1.44m) high-density floppy disk drive.

Parallel printer port.

DOS 3.0 or higher.



# Precautions

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The following precautions must be followed carefully. Failure to observe these precautions may result in injury, loss of life and/or, damage to property. Use these precautions as a starting point for safe operation of the MD-2 system. Use common sense whenever using equipment like this to insure safe and productive results. If you have any safety-related questions that aren't addressed here, give us a call.

- Never attach or remove motor or computer cables while power is applied to the MD-2 unit or the computer.
- Never apply power to the MD-2 unit while the computer is turned off. Connecting the MD-2 and the computer to the same power strip will eliminate this possibility.
- Place the MD-2 unit in a well ventilated area to minimize heat buildup. Mount the motors so that heat buildup is minimized.
- Never use an inappropriate power source.
- Don't use the Input/Output port incorrectly.
- Never use the MD-2 with inappropriate equipment or in inappropriate environments.
- Don't use the MD-2 in situations that could cause danger to life or property
- Don't replace a blown fuse. This indicates a failure. Return the unit to the factory for repair.
- Disable any TSR (Terminate and stay resident) programs during MD-2 operation. Not doing this could result in erratic motor speed and lost steps but not damage to the system.
- When writing custom software, never send an invalid pattern to the MD-2. See the custom software section of this guide for more information.
- Do not remove the cover of the MD-2 unit or disassemble the motors.
- Never exceed the specifications of the system.



**Failure to observe these precautions could result in injury, loss of life and/or, damage to property.**

# Hardware Installation

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Due to the simplicity of the MD-2 system, installation normally takes less than 20 minutes. The user is required to have average computer experience including a minimal knowledge of DOS commands. It will not be necessary to open your computer.

- 1 Check your package for the following items,
  - (1) MD-2 driver box.
  - (2) Stepper motors with switches.
  - (2) Stepper motor cables.
  - (1) 115 VAC power cord.
  - (1) Parallel printer cable.
  - (1) Manual.
  - (1) MD-2 software package.
  - (1) Warranty registration card.
- 2 Fill out the warranty registration card and return it! This will insure that you receive information about software updates and new products, and allows us to provide technical support more effectively.
- 3 Begin by turning off your computer and the power switch on the MD-2 system.
- 4 Connect the stepper motors to the MD-2 driver box using the motor cables. Never connect or remove the motor cables while power is on.
- 5 Connect the MD-2 to your parallel printer port using the cable supplied.
- 6 Plug the MD-2 into a 3-prong, 115 VAC outlet using the AC power cord.
- 7 You can now turn on your computer, then the MD-2 system. The power light should come on.
- 8 Insert the MD-2 program diskette into drive A: and type the following at the DOS prompt:

```
A: (ENTER)
MD2 (ENTER)
```

This is the simplest way to run the MD-2 program, but we suggest that you copy the MD-2 software to your hard disk. See the section covering the MD-2 program for information concerning this. Before moving motors with the MD-2 program, you must select the CALIBRATE item from the OPTIONS menu. You can then enable the MD-2 system, move motors using the keyboard, mouse or joystick and experiment with all motor parameters. The default parameters are normally adequate for initial experimentation, but fine tuning will be required for best results with your particular application. See the MD-2 program section for specific details on operation. On-line help is provided within the program to answer common questions.

# Operation

## Power Switch

A power switch is provided to control the MD-2 system when it is connected to a 115 VAC outlet. Never apply power to the MD-2 system while the computer is OFF. At any time the power may be turned OFF without harming the motors or electronics and is useful for emergency stops. This switch will not control power to the MD-2 if a battery is being used to provide power.

## Power Light

The lights on the front panel of the MD-2 enclosure indicate the current condition of the power supply, motors and switches. The 'POWER' light should be ON whenever 115VAC power is being supplied to the unit and the power switch is in the ON position or when battery power is being applied at the battery connector on the rear panel.

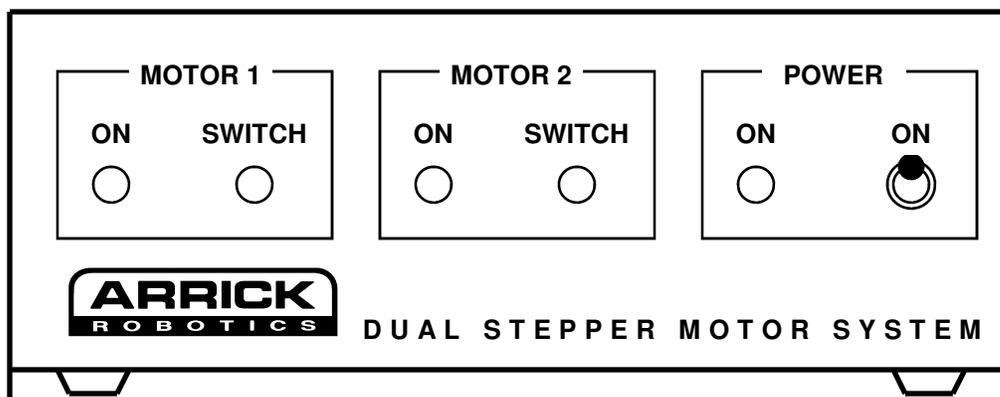
## Switch Lights

The 'SWITCH' lights will be ON whenever a switch is pressed. When a switch is pressed, the input signal to the MD-2 is connected to ground (0 volts).

## Motor Lights

The 'MOTOR' lights will be ON whenever the motors are energized. These lights do not necessarily indicate motor movement but only that power is applied to them.

See the troubleshooting section if the MD-2 does not operate as expected.



# **Computer Issues**

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The software provided with the MD-2 system turns your computer into a powerful motor controller using the parallel printer port. The MD-2 driver box contains the power supply and drive electronics for the motors. The actual motion control functions are performed by the computer and software.

## **Real-Time Control**

To move the motors, the computer must send continuous signals to the MD-2 system. Because of this real-time control, the computer must not be interrupted to perform other tasks while moving the motors. If interruptions occur, the consistency of the signals will be compromised resulting in jerking or rough motor movement and reduced maximum motor speed. The following items can cause problems with these real-time signals -

- Communications port interrupts.
- Mouse interrupts.
- TSR (Terminate and Stay Resident) programs running in the background.
- Hard/floppy disk operation.
- Operating systems that steal processing time such as Windows and OS/2
- Power conservation features.

To minimize these problems, a special parameter has been added to the MD-2 software called 'Leave Interrupts On'. This parameter allows the user to turn off interrupts during motor moves reducing mouse and communications interrupts. Some operating environments such as OS/2 will not let the program disable interrupts which prevents this from working successfully. Check the CONFIG.SYS and AUTOEXEC.BAT files for programs that may operate in the background unexpectedly and remove them when optimum MD-2 performance is required. Some computers have special features that will automatically reduce the computer speed and performance when keyboard or mouse activity is not detected. This will result in a sudden change in motor speeds. Most systems allow these features to be disabled.

## **Using Windows and OS/2**

Operating environments such as Windows and OS/2 are constantly performing operations in the background which can cause problems with a real-time system such as the MD-2. It is possible to greatly enhance the MD-2's performance in these environments by adjusting configuration files, but it is not possible for the system to perform as good as it does in DOS. A PIF (Program Information File) and icon is provided to allow you to operate the MD-2 program in the Windows V3.1 environment. It is necessary to calibrate the MD-2 in this environment if the MD-2 will be used there. Don't use a calibration file that was created in DOS, in another environment such as Windows. Ultimately, experimentation will determine if the MD-2 can be operated at an acceptable level of performance in your environment. Additional information about this subject can be found in your computer manual and operating system manual.

# **Software**

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The MD-2 system is provided with software which allows you to perform almost any motion control task imaginable. The software allows the MD-2 system to be controlled interactively with the keyboard and joystick, from the DOS prompt, from batch files, or from custom programs written in BASIC, C and PASCAL.

## **MD-2 Program**

The MD-2 program allows the operator to control the MD-2 dual stepper motor system interactively via the keyboard and joystick. All motor parameters can be edited and experimented with. Motors can be moved and advanced moves such as circles, arcs and grids are also possible. Motion control programs can be loaded, saved, edited and executed. Motion programs as large as 32K can be created automatically using the teach mode which writes code for you. Other features include input bit reading, output bit control, motor speed calibration, standby mode control and port identification. Programs can be run from the DOS command line or from batch files.

## **Level 1 Subroutine Library**

The level 1 subroutine library provides the routines necessary to build simple custom motion control programs in the following languages: Q-Basic, Quick-Basic, GW Basic, Visual-Basic/DOS, Visual-Basic/Windows, C and Pascal. Easily used to create custom programs which integrate motion control with data acquisition equipment. Elaborate features are left out to reduce complexity and program size.

## **Level 2 Subroutine Library**

The level 2 subroutine library provides the routines necessary to create complex motion control subroutine programs in Quick-Basic, Visual-Basic, Visual-Basic and C. Includes complex motion control features such as linear and circular interpolation, ramping, backlash compensation, units conversion and soft limits. A motion program interpreter and parameter editing screen along with other advanced features are also included. The level 2 subroutine library was used as the basis for creating the MD-2 program.

# **Parallel Printer Ports**

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The MD-2 system connects to the parallel printer port of your computer. There can be as many as 3 printer ports on your computer. Since each port can be attached to an MD-2, a total of 6 motors can be controlled with a single computer. Each port has its own unique address. The three possible addresses are 3BC, 378 and 278. When adding a new printer port to your computer, make sure that no two ports have the same address. The MD-2 software refers to the motors connected to port 3BC as motors 1 and 2, 378 as motors 3 and 4, port 278 as motors 5 and 6. Your computer may have only one or two ports. Since the motor numbers are determined by which port they are connected to, your system may have motors 3 and 4 but not 1 and 2. you may wish to keep your 3BC port connected to your printer since DOS refers to it as LPT1: or PRN: which is the primary default printer. Parallel printer ports are very inexpensive, easy to install and are normally available at computer stores or by mail-order. There are usually jumpers on the boards that allow you to select the desired port address. If the card has a jumper to set the interrupt request (IRQ), its position is not important for operation with the MD-2 system.

# ***Theory of Operation***

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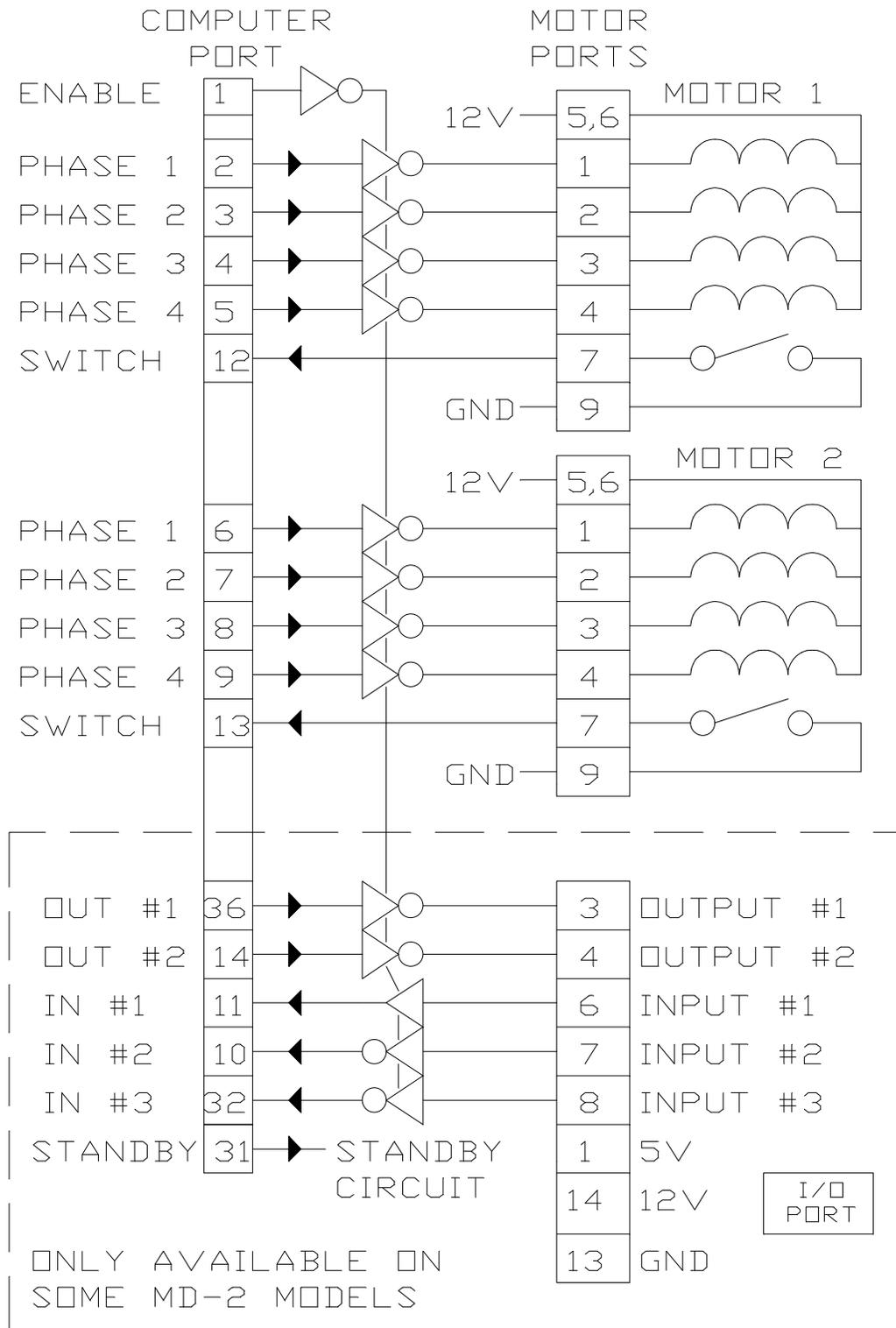
A stepper motor is a special type of motor that lends itself to precise positioning under digital computer control. Unlike servo motors which require encoder feedback, high-speed electronics and expensive amplifiers, a stepper motor can be operated open-loop and without expensive electronics. Although a stepper motor system normally has less performance than a servo system, stepper systems have fewer components, are easier to operate, less expensive and require almost no maintenance.

A stepper motor is unlike other motors in its construction and operation. The motor has four copper coils which create a magnetic field when energized. This field reacts to the permanent magnet connected to the shaft of the motor and causes it to rotate. The sequence in which these coils (or Phases) are energized determines the step angle and direction. The motor will advance one step as each new phase pattern is sent. If the coils are energized but not switching, the motor will remain in the current position and resist rotation. This resistance to motion is referred to as the holding torque. Brushes are not used in stepper motor construction resulting in a long, maintenance-free motor life. Due to their construction, stepper motors can not be harmed or overheated by stalling or binding of the shaft. Motor and driver heating is normal for stepper systems and must be considered during installation and operation. If holding torque is not required, motor heating can be minimized by de-energizing the motor coils when the motion is complete. The running (dynamic) torque of the motor will decrease as the step rate increases. Lost steps will occur if the motor is stepped too fast for a given load, but this will not cause harm to the motor or driver but will cause the computer to lose track of the motor's position. See the torque curves provided in this guide for more information.

A mechanical plunger style switch is attached to each motor cable to provide home position feedback to the computer. When the system is first powered on, a home positioning sequence which uses the switch should be executed under software control to establish the motor position at location zero. All other positions are relative to zero. Optical and other types of switches can also be attached to this input.

The MD-2 system requires a source of control signals to move the motors and to read the switches. Software is provided which will allow a standard IBM style personal computer to perform this function through the parallel printer port. Motion control programs are supplied to control the system along with subroutine libraries for projects requiring custom software. Since as many as three different parallel printer ports can be installed into an IBM style personal computer, 6 motors can be controlled by a single computer.

# Functional Diagram



# Input / Output Port

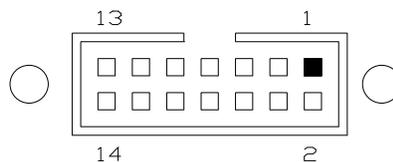
Some MD-2 systems have a miscellaneous input/output (I/O) port which can be used to read digital input signals and to control digital output signals. There are 3 digital inputs which can read signals from sensors and switches. Possible uses for input signals are user-defined push-buttons, over-travel sensing and tool breakage detection. There are 2 digital output signals that can be used to control relays which can, in-turn, control tools such as drills, coolant, lasers and lamps.

All of these signals conform to TTL logic levels meaning that a logic 1 is 5 volts and a logic 0 is 0 volts. Both input and output signals are active low. Connecting a digital input to logic 0 (0 volts) indicates that a switch is activated. This allows the connecting of multiple switches in parallel. Setting a digital output to ON, (0 volts), causes the external device to turn ON.

The I/O port is a 14-pin male, dual-row header connector found on the rear panel of the MD-2 above the computer connector. This type of connector is common and typically connects to standard flat cable.

The I/O port connector also contains several signals that may be useful for external circuits such as +5 volts DC, +12 volts DC, ground and motor switch input signals.

It is important that no more than 25ma of current be drawn from the signals on the I/O port. This should be enough to control solid state relays and other small devices but not enough to drive mechanical relays, solenoids and other larger devices directly. Always protect I/O port signals from high voltages and spikes to prevent damage to the internal MD-2 circuitry.



PIN	DESCRIPTION
1	5 volts DC @ 25ma
3	Output #1, active low
4	Output #2, active low
6	Input #1, active low
7	Input #2, active low
8	Input #3, active low
11	Motor 1 switch, active low
12	Motor 2 switch, active low
13	Ground
14	12 volts DC @ 25ma

## Detailed I/O Port Pin Descriptions

The MD-2 system must be enabled before any output signals can be controlled. This prevents the output signals from being turned on when power is initially applied. The MD-2 subroutine libraries provide this initialization code. The following BASIC statements can also be used to enable the MD-2 system. The example program code here uses a base address of 3BC hex, but your port may be at 378 hex or 278 hex.

```
'Turn off outputs and enable the MD-2.  
OUT &H3BC+2, &H05
```

```
'Disable the MD-2.  
OUT &H3BC+2, &H04
```

### Pin # 1, 5 VDC @ 25 ma

5 volt DC power supply capable of supplying 25ma of current. This pin can be used to supply small amounts of power to external circuitry. Use this pin in conjunction with output pins to control solid state relays (see below). Drawing more than 25ma of current could cause damage to the MD-2.

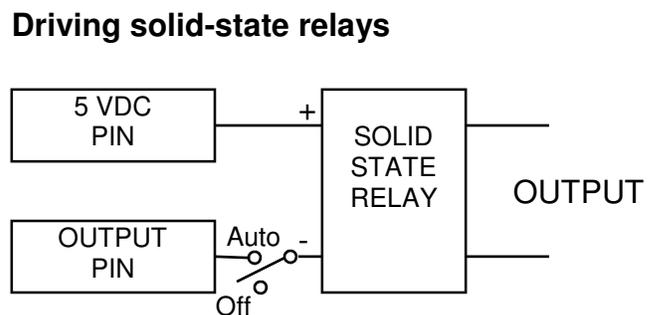
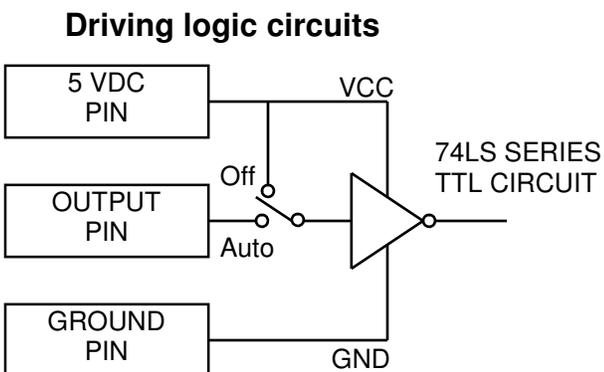
### Pin # 3, Output # 1

This TTL level output can be controlled with a simple software 'OUTPUT' command. The drive circuit allows the pin to sink up to 25ma. The pin is active low meaning that low (0 volts) indicates ON. This pin is capable of driving a digital circuit or a solid-state relay which can control other devices. When driving small relays or other inductive loads, connect a flyback diode to protect the internal drive circuit. A manual switch can be placed in the external circuit to allow manual control for safety purposes. Remember to enable the MD-2 system before controlling this and other output signals (See above). The following BASIC statements can be used to control this output signal:

```
'Turn output # 1 pin to low, 0 volts.  
OUT &H3BC+2, INP(&H3BC+2) OR &H08
```

```
'Turn output # 1 pin to high, 5 volts.  
OUT &H3BC+2, INP(&H3BC+2) AND &HF7
```

### Typical output circuit diagram



Use a solid state relay having a 3 volt DC control input such as the CRYDOM D2400 series.

### Pin # 4, Output # 2

This output pin is identical to output # 1 in terms of drive capability and usage. The following BASIC statements can be used to control this output signal.

```
'Turn output # 2 pin to low, 0 volts.  
OUT &H3BC+2, INP(&H3BC+2) OR &H02
```

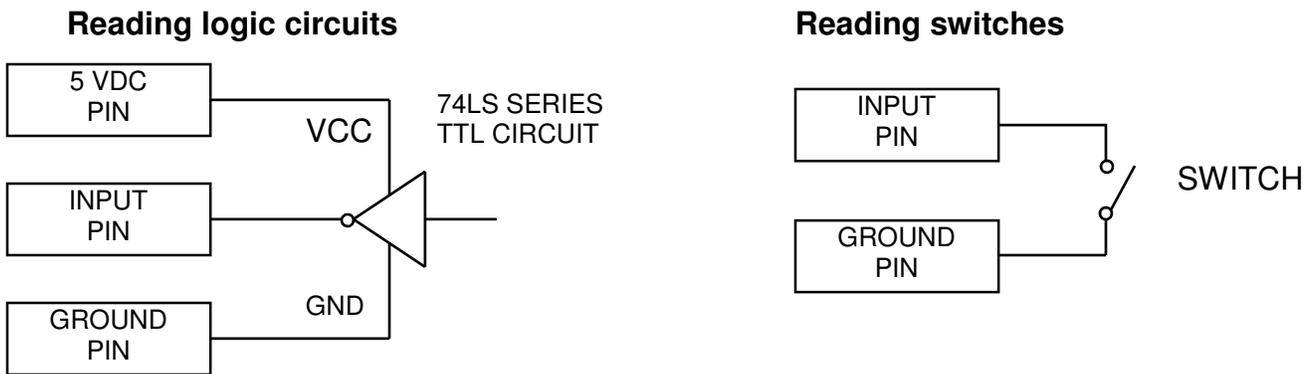
```
'Turn output # 2 pin to high, 5 volts.  
OUT &H3BC+2, INP(&H3BC+2) AND &HFD
```

### Pin # 6, Input # 1

This TTL level input pin can be used to read switches, sensors and other input devices. Normally this input is simply grounded to detect an input. The following statement can be used to read this input signal.

```
PRINT (INP (&H3BC+1) AND &H80)
```

### Typical input circuit diagram



### Pin # 7, Input # 2

This TTL level input pin has the same capability as other input pins. The following statement can be used to read this input signal.

```
PRINT (INP (&H3BC+1) AND &H40)
```

### Pin # 8, Input # 3

This TTL level input pin has the same capability as other input pins. The following statement can be used to read this input signal.

```
PRINT (INP (&H3BC+1) AND &H08)
```

### **Pin # 11, Motor # 2 switch input**

This TTL level input pin has the same capability as other input pins and carries the same input signal that appears on the motor cable. It can be used in addition to, or instead of the motor switch. Normally the input is connected to ground to be detected. The following statement can be used to read this input signal.

```
PRINT (INP (&H3BC+1) AND &H10)
```

### **Pin # 12, Motor # 1 switch input**

This pin is the same as above, but is connected to the motor 1 switch signal. The following statement can be used to read this input signal.

```
PRINT (INP (&H3BC+1) AND &H20)
```

### **Pin # 13, Ground**

This signal should be connected to the external circuitry for correct operation. Input signals can be connected to this ground to be detected.

### **Pin # 14, 12 VDC @ 25 ma**

12 volt DC power supply capable of supplying 25 ma of current. This pin can be used to supply small amounts of external circuitry. Drawing more than 25 ma of current could cause damage.

## ***Holding and Standby Mode***

---

When a stepper motor is energized with a step pattern that is not changing, it produces holding torque which will cause the motor's shaft to resist movement. While the motor is in this holding mode, heat is generated. Some applications require that the motor's shaft resist motion between moves and others do not. If holding torque is not needed, disable the MD-2 which will de-energize both motors and reduce motor heat. If holding torque is needed, keep the MD-2 enabled. The motors and the MD-2 drive electronics are designed to withstand the heat generated.

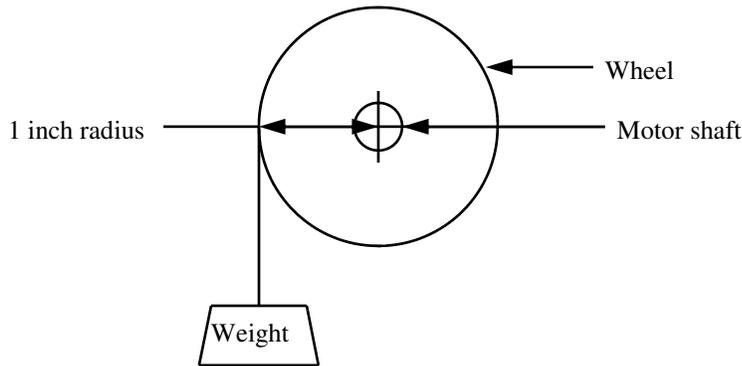
If only partial holding torque is needed, it is possible to place the MD-2 into standby mode. Standby mode is not available on the basic MD-2 system. Standby mode reduces the motor current by 50% which greatly reduces heat buildup while maintaining some holding torque. Trying to move a motor while standby mode is enabled may result in erratic behavior since the torque has been reduced as a result of lower current. Standby mode affects both motors connected to the MD-2 system.

The MD-2 program and the level 2 subroutine library provides control of standby mode. If you are writing a program from scratch, the following BASIC code can be used to control standby mode.

```
'TURN STANDBY MODE OFF.  
OUT &H3BC+2, INP (&H3BC+2) OR &H04  
  
'TURN STANDBY MODE ON.  
OUT &H3BC+2, INP (&H3BC+2) AND &HFB
```

# Motor Torque

Torque is the term used to refer to the rotational strength of a motor. Torque is measured in oz/in, ft/lbs, or any other combination of length and weight. The length indicates the distance from the center of the motor's shaft to the position of the weight.



In this example, the weight is suspended on a string by a wheel that has a radius of 1 inch. The weight is 16 ounces and the length is 1 inch. To move this weight, the motor would have to have at least 16 oz/in of torque. See the specification section for detailed torque information for each MD-2 model.

## Holding Torque

Holding torque is the strength of the motor's resistance to rotation while energized but not moving. Holding torque is usually measured with 2 phases energized to provide the maximum rating. If a motor has 50 oz/in of holding torque, it will resist rotation until the weight at the end of a wheel having a 1 inch radius exceeds 50 ounces.

## Detent Torque

Detent torque is the motor's residual torque seen when the motor is not energized. This can be experienced by simply turning the shaft of the motor manually while it is disconnected from the driver. A gear reducer will magnify this detent torque and can often cause the mechanical system to resist back-driving even when the motor is off.

## Pull-in Torque

The maximum torque that the motor will start and continue to run at without losing steps. This value is always less than the pull-out torque.

## Pull-out Torque

The maximum torque that can be applied to the shaft of the motor and not cause lost steps. This value shows the motor's strength after being accelerated.

## Torque Curve Chart

A torque curve chart will show how much torque the motor has available at various speeds. The charts will show that the torque decreases as the motor's speed increases. The specification section shows torque curves for all MD-2 models.

# Step Types

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Step motors operate by energizing their windings (phases) in certain sequences called phase patterns. Changing from one pattern to another causes the motor to move one step. There are 3 different types of phase pattern modes. In half step mode, the motor alternates between one and two motor phases being energized which results in steps that are half the size of full steps. Half steps are usually .9 degrees but differ depending on the motor. Half step mode is the most common since it has twice the resolution of full step modes which reduces vibration. When in half step mode, every other step is stronger than the previous one. There are two types of full step modes. Double-phase full step mode always energizes two motor phases at a time which results in more torque and motor heat. Single-phase full step mode always energizes one motor phase at a time which results in less torque and less motor heat. Both full step modes normally result in steps that are 1.8 degrees. The MD-2 program and the level 2 subroutine library allows you to change the step type used. In most applications half step mode should be used to minimize vibration and increase resolution.

The following charts show the various patterns used to control the 4 motor windings (phases). A zero indicates that a winding is turned ON (energized).

## Half Step Phase Pattern

#	4	3	2	1
1	1	1	1	0
2	1	1	0	0
3	1	1	0	1
4	1	0	0	1
5	1	0	1	1
6	0	0	1	1
7	0	1	1	1
8	0	1	1	0

## Full-Double Step Phase Pattern

#	4	3	2	1
1	1	1	0	0
2	1	0	0	1
3	0	0	1	1
4	0	1	1	0

## Full-Single Step Phase Pattern

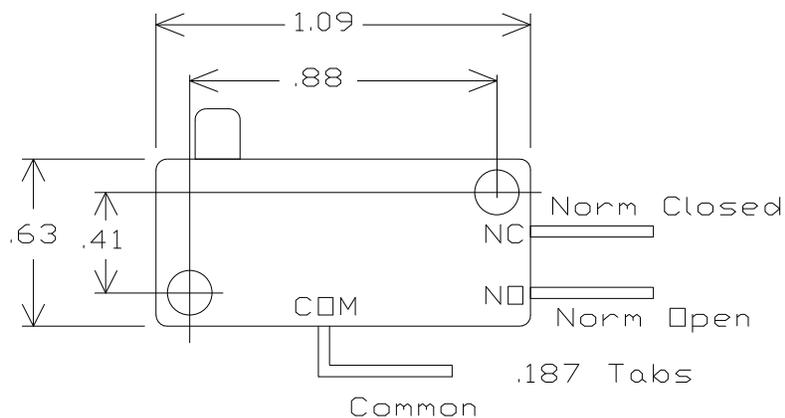
#	4	3	2	1
1	1	1	1	0
2	1	1	0	1
3	1	0	1	1
4	0	1	1	1

# Switch Usage

Each motor cable has provisions for one switch input which can be read by the software. The programmer has complete control over the switches and can react in any way upon switch closure or can even choose to ignore it. A mechanical plunger style switch is provided with the system, but other types of switches or sensors can be used.

Normally the switch inputs are used to accomplish 'HOME' positioning when the system is first powered up to establish a reference point for other motion. Software is provided which uses the switches to find the 'HOME' position. The 'HOME' positioning software sequence first moves the motor in reverse until the switch is depressed, then moves the motor forward until the switch is no longer depressed. This sequence has the effect of preloading the mechanical system in the forward direction and can increase the precision of subsequent moves which also approach from this direction.

The switch inputs may also be used as general purpose input which can be read by the software and behave as needed. Optical switches and other sensors may be attached in place of the mechanical switch if needed. Any switch or sensor attached must drive the switch input signal to ground to be detected. See the connector pinout section for detailed information on switch connections.



# Battery Usage

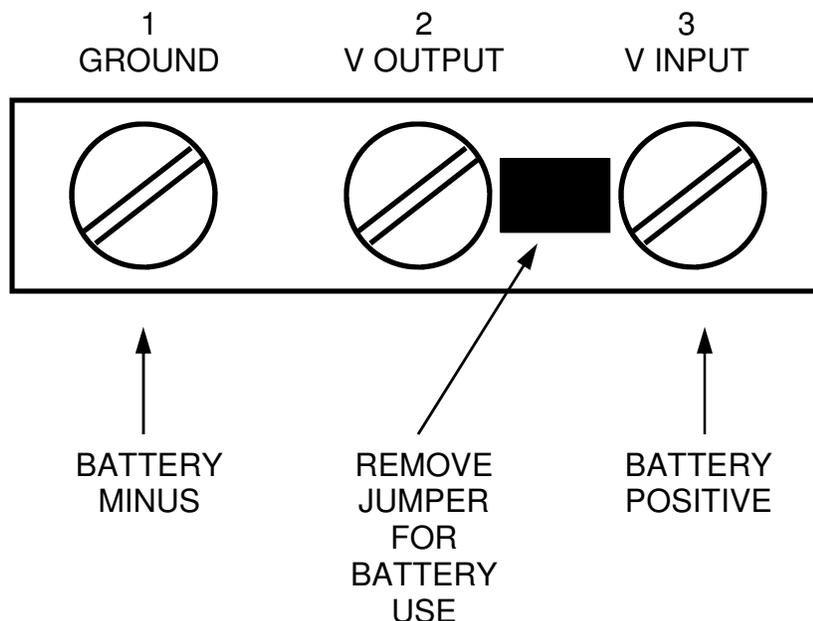
The MD-2 system can be powered by a large battery such as a gel-cel or a car battery when AC power is unavailable. This is useful for remote applications such as telescope positioning. The type and size of battery depends on the MD-2 model and the length of operating time required. The following chart lists the voltages and maximum current requirements. Operation of the MD-2 outside of these voltage ranges may cause damage to the MD-2 system or to the computer.

MD-2	14 +/-2 volts @ 5 amps max.
MD-2a	28 +/-4 volts @ 5 amps max.
MD-2b	28 +/-4 volts @ 13 amps max.
MD-2c	28 +/-4 volts @ 17 amps max.

Most car batteries will produce about 14 volts, two car batteries in series will produce about 28 volts. Several batteries can be placed in parallel to provide power for a longer time.

A 3-screw terminal strip is provided on the rear panel of the MD-2 to attach the external battery. A jumper provides switching between the internal power supply and the external battery. To connect a battery, remove the jumper and attach the ground lead to pin 1 and the positive lead to pin 3 using 14 AWG wire. A fuse should be placed in series with the battery leads for protection against overloads. A switch should also be used since the front panel power switch only operates during AC operation.

- 1 - Ground
- 2 - Internally generated power (Output)
- 3 - Externally applied power (Input)



# Connector Pinouts

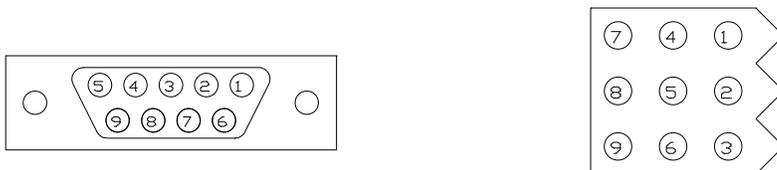
The following connector pinouts are provided for those wishing to attach non-standard equipment to the MD-2 system. Errors in attaching non-standard equipment may result in damage to the computer or the MD-2 system. The battery input connector and the miscellaneous I/O connector pinouts are discussed in sections of this manual dedicated to their function.

## Motor / Switch Connectors

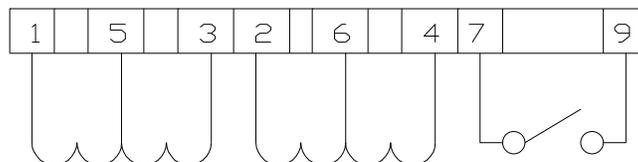
Two motor/switch ports can be found on the MD-2 rear panel. The type of connector used will depend on the current and voltage requirement of the motors supplied with the package. For low power motors, a 9-pin D-Sub connector also known as a DE9 is used. For high power motors, a 9-pin nylon Molex-style connector is used. Most Radio Shack stores will carry both types of connectors along with connector hardware such as hoods and pins.

- 1 - Motor phase 1
- 2 - Motor phase 2
- 3 - Motor phase 3
- 4 - Motor phase 4
- 5 - Motor phase 1 and 3 common
- 6 - Motor phase 2 and 4 common
- 7 - Switch input, active low
- 8 - +5 volts DC @ 25 ma.
- 9 - Ground

## Connectors as viewed from the rear panel



## Typical wiring for the motor and mechanical home switch



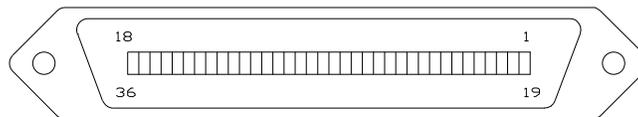
## Computer Interface Connector

The computer port on the rear panel of the MD-2 motor driver is designed to connect to an IBM style personal computer's parallel printer port. The computer will have a female 25-pin D-sub style connector. The MD-2 has a 36-pin female centronics style connector like many printers. This arrangement allows easy connection of the MD-2 system using a standard parallel printer cable. The industry standard part number for the mating male 36-pin centronics connector is 57-30360.

CPU 25 PIN	MD-2 36 PIN	NORMAL NAME/USAGE	MD-2 NAME/USAGE
1	1	-Strobe	MD-2 enable, active low
2	2	Data bit 0	Motor 1, phase 1, active low
3	3	Data bit 1	Motor 1, phase 2, active low
4	4	Data bit 2	Motor 1, phase 3, active low
5	5	Data bit 3	Motor 1, phase 4, active low
6	6	Data bit 4	Motor 2, phase 1, active low
7	7	Data bit 5	Motor 2, phase 2, active low
8	8	Data bit 6	Motor 2, phase 3, active low
9	9	Data bit 7	Motor 2, phase 4, active low
10	10	-Acknowledge	* Input # 2
11	11	Busy	* Input # 1
12	12	Paper out	Motor 1 switch, active low
13	13	Select	Motor 2 switch, active low
14	14	-Auto LF	* Output # 2
15	32	-Error	* Input # 3
16	31	-Initialize	* Standby Mode
17	36	-Select In	* Output # 1
18-25	19-25	Ground	Ground

\* Used only by models having I/O port and standby feature.

## Connector as viewed from the rear panel



# Custom Subroutines

This section covers the concepts required to write custom motion control subroutines from scratch. Writing these subroutines will only be necessary for very special applications since most custom software can be written using the level 1 or level 2 subroutine libraries provided. Programmers may wish to read this section to become more familiar with the software even if the subroutine libraries will be used.

Motion control subroutines must manipulate the bits on the parallel printer port that normally go to a printer. Most programming languages provide OUTPUT and INPUT commands to control ports. The software must send the correct sequence of 1's and 0's to control the motor's phases. The software must also control various other bits on the port to provide functions such as MD-2 enable and the reading of the home switches.

There are three possible phase patterns sequences, full step single phase, full step double phase, and half step. See the section on step types for details on the bit patterns used to create these sequences. Sending these patterns to the MD-2 system will cause the motor to step each time the pattern changes. Reversing the sequence will cause the motor to reverse direction. Always continue with the next pattern in the sequence regardless of speed or direction. The following pattern will cause the motor to move in half step mode.

## Half Step Phase Pattern

#	4	3	2	1
1	1	1	1	0
2	1	1	0	0
3	1	1	0	1
4	1	0	0	1
5	1	0	1	1
6	0	0	1	1
7	0	1	1	1
8	0	1	1	0

The numbers 4,3,2,1 at the top of the column represent the motor phases. The following chart shows which bit at the port controls which motor phase.

SIGNAL NAME	ADDRESS	BIT	ACTIVE STATE
Motor 1, phase 1	BASE	0	0
Motor 1, phase 2	BASE	1	0
Motor 1, phase 3	BASE	2	0
Motor 1, phase 4	BASE	3	0
Motor 2, phase 1	BASE	4	0
Motor 2, phase 2	BASE	5	0
Motor 2, phase 3	BASE	6	0
Motor 2, phase 4	BASE	7	0
Motor 1, switch	BASE+1	5	0
Motor 2, switch	BASE+1	4	0
MD-2 enable	BASE+2	0	0

It is important not to disturb one motor's bits while controlling another. One way to accomplish this is to read the port, set only the required bits, then write back the entire byte.

Speed control is accomplished by providing a software delay loop between each step. Ramping can be performed by gradually decreasing and increasing the delay as steps are given.

After a motion is complete, the programmer may leave the phases energized with the last step pattern which will result in holding torque. If holding torque is not required, the programmer may read and save the last step pattern issued then de-energize the phases. This will result in a much cooler motor and driver.

An IBM style personal computer can accommodate up to three different parallel printer ports. Their base addresses are 3BC, 378 and 278 hex. The printer port data register which controls the motor's phases resides at this base address. At the base address + 1 resides the status register which is used to read the status of the home switches. At the base address + 2 resides the control register which is used to enable the MD-2 and control output port functions (see the section on the Input/Output port).

<b>MOTORS</b>	<b>BASE ADDRESS-HEX</b>	<b>BASE ADDRESS-DECIMAL</b>
1 & 2	3BC	956
3 & 4	378	888
5 & 6	278	632

The following example program will move motor #1 forward in half step mode continuously.

```
10 A = &H3BC           'SET THE PORT ADDRESS.
20 OUT A, &HFF         'SET ALL PHASES OFF.
30 OUT A + 2, 5       'TURN ON THE MD-2.
40 OUT A, &HFE         'OUTPUT THE STEP PATTERN.
50 GOSUB 1000         'DELAY FOR SPEED CONTROL.
60 OUT A, &HFC
70 GOSUB 1000
80 OUT A, &HFD
90 GOSUB 1000
100 OUT A, &HF9
110 GOSUB 1000
120 OUT A, &HFB
130 GOSUB 1000
140 OUT A, &HF3
150 GOSUB 1000
160 OUT A, &HF7
170 GOSUB 1000
180 OUT A, &HF6
190 GOSUB 1000
200 GOTO 40
1000 FOR I=1 TO 1000 : NEXT I : RETURN
```

It may be necessary to change line 10 to reflect a different port address. To move motor #2, change &HFE to &HEF and so on. To move both motors, change &HFE to &HEE and so on.

It is very important to turn all motor phases OFF before turning the MD-2 system on since the contents of the parallel port data register is unknown and may contain an invalid pattern which could damage the MD-2 system.

The following BASIC statement will print the last pattern issued to the port:

```
PRINT HEX$(INP(&H3BC))
```

The following BASIC statement will turn OFF all phases of both motors:

```
OUT &H3BC, &HFF
```

The switches may be read in software with a few simple statements as this BASIC program example shows:

```
IF (INP(&H3BC+1) AND &H20)=0 THEN
    PRINT "MOTOR 1 SWITCH ON"
ELSE
    PRINT "MOTOR 1 SWITCH OFF"
ENDIF
```

```
IF (INP(&H3BC+1) AND &H10)=0 THEN
    PRINT "MOTOR 2 SWITCH ON"
ELSE
    PRINT "MOTOR 2 SWITCH OFF"
ENDIF
```

## ***Other Computers***

---

The MD-2 system was designed for use with an IBM style personal computer but can be used with any computer having 9 bits of digital output and 2 bits of digital input. Use of the input/output port will require another 5 bits. The programmer must have direct and complete control over the bits and signals going to and coming from the port. Most parallel printer ports meet these requirements.

When connecting the MD-2 system to a computer, refer to the connector pinouts in this guide. It is important to use the strobe signal to disable the MD-2 during power-up to prevent an invalid phase pattern from reaching the system. When the strobe signal is low (logic zero) the MD-2 will be enabled.

Use the information in the section describing the writing of custom programs along with the subroutine libraries to create programs for use on other computers.

# ***Gear Reduction***

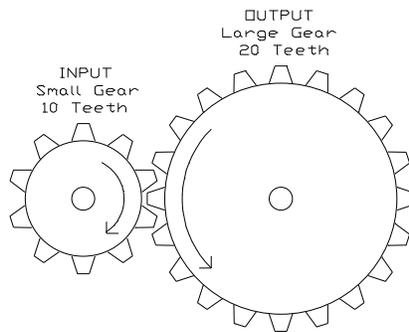
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Many applications can not be driven directly from the motor's shaft but require some form of reduction to increase torque and resolution at the expense of speed. This reduction may be accomplished with gears, pulleys, friction wheels or some combination of these.

Reduction has several effects on the output of the positioning system.

1. Increase resolution. (The smallest movement possible)
2. Increase torque. (Strength)
3. Decrease speed.

Reduction can be accomplished by connecting a small gear to a large one.

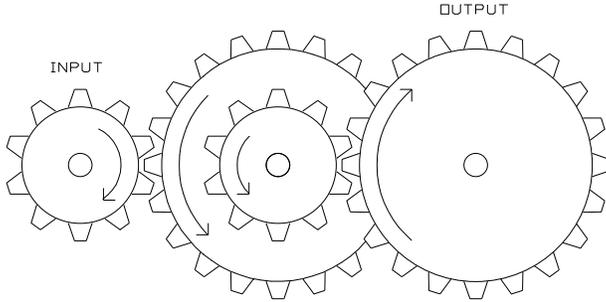


The gear reduction ratio in this example can be found two ways:

1. The ratio of gear diameters.
2. The ratio of gear teeth.

Since there are 10 teeth on the small gear and 20 teeth on the large one, the ratio is 2:1. This arrangement will double the resolution and torque while cutting the speed in half. These same concepts will work with pulleys and friction wheels.

Multiple stages of gearing can accomplish larger reduction ratios as this example shows:



The final gear reduction ratio in this example is:  $2:1 \times 2:1 = 4:1$

Other gear reduction calculations:

Specifications before any reduction:

Resolution: .9 degrees per step  
Torque: 30 oz/inches  
Speed: 600 steps per second  
X .9 degrees = 540 degrees per second

Specifications after a reduction ratio of 100 to 1 (100:1)

Resolution: .009 degrees per step, .54 min, 32.4 sec  
Torque: 3000 oz/inches or 15.6 ft/lbs  
Speed: 600 steps per second  
@ .009 degrees = 5.4 degrees per second

After a reduction ratio of 1000 to 1 (1000:1) :

Resolution: .0009 degrees per step, .054 arc min, 3.24 arc sec  
Torque: 30000 oz/inches or 156 ft/lbs  
Speed: 600 steps per second  
@ .0009 degrees = .54 degrees per second

These calculations make the assumption that the gear box efficiency is 100%, that there is no friction, and that the gear box construction can handle the torque output. The final torque and maximum speed will be somewhat less than the ideal values.

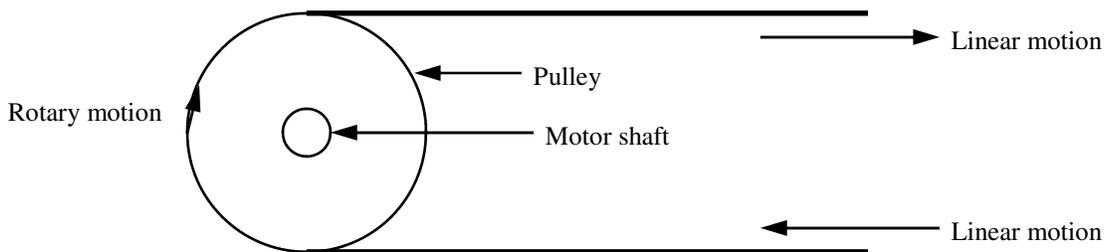
As these examples demonstrate, the effects on resolution, torque and speed are proportional to the gear reduction ratio.

The maximum speed that the motor is capable of moving will vary depending on the friction and inertia of the load. The torque of stepper motors decreases as the speed increases. Lost steps will occur as the motor reaches the maximum speed limit. The user must determine the maximum safe motor speed by experimenting to find the speed at which steps are obviously lost and then reducing it by 30% to 50%. A jerking motion or erratic motor behavior are indicators of lost steps.

# Pulley and Belt Drives

Pulley and belt drives can be used to convert rotary motion from a motor into linear motion. The resolution and available torque of the belt-driven application is a function of the diameter of the pulley. The following example shows a pulley with a diameter of .637. The stepper motor has .9 degree steps, then each step of the motor will move the belt .005 inch.

$$.637\text{dia.} \times 3.14 = 2 \text{ inch circumference} / 400 \text{ steps per revolution} = .005 \text{ inch travel per motor step}$$

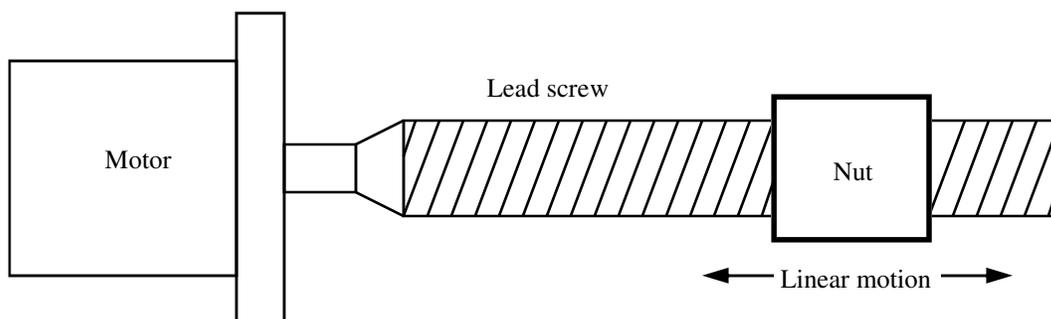


# Lead-Screw Drives

Lead screws are another common way used to convert the rotary motion from a motor to a linear motion. Lead screws normally provide more overall reduction than a pulley drive. The torque is greatly increased along with the resolution at the expense of speed. The efficiency of a lead screw system varies greatly depending on the material used, lubrication and bearing arrangement. This example uses a lead screw with 10 threads per inch.

$$10 \text{ threads} \times 400 \text{ steps per motor revolution} = 4000 \text{ motor steps per inch of travel.}$$

$$1 \text{ inch} / 4000 \text{ steps} = .00025" \text{ of travel per motor step.}$$



# ***Backlash Compensation***

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Backlash is a term used to describe the amount of mechanical looseness in the positioning system. When gears are used, this looseness is caused by spacing between the teeth of the gears. In systems where belts and pulleys are used, backlash is caused by belt stretch. Bearings, couplings and mounting hardware can also be a source of backlash.

Provisions have been made in the MD-2 program and in the level 2 subroutine library to compensate for backlash. Backlash values are represented in the quantity of steps or units and are used to make corrections whenever the motor's direction changes. The user can determine the backlash by first moving the motor in the forward direction until final application motion is observed, then start moving reverse while counting steps or units and observing motion. The quantity of steps or units required to start the motion of the mechanical system is the backlash value. When this value is entered into the MD-2 software, anytime the direction of the motor changes, this quantity of steps will be added to compensate for backlash. This method can greatly increase a system's bidirectional positioning

## ***Suggested Reading***

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The following list of reading material is provided for those seeking additional information on motion control subjects.

### **Art and Practice of Step Motor Control**

Albert C. Leenhout  
Intertec Communications Inc.  
2472 Eastman Ave. Bldg. 33-34  
Ventura, CA 93003  
(805) 658-0933

This book contains information about the theory behind step motors and their drive systems. A diskette is included with some BASIC programs for use on an IBM personal computer. Topics include motor construction, drive techniques and microstepping.

### **Automation Magazine**

1100 Superior Ave.  
Cleveland, OH 44114-2543  
(216) 696-7000

Magazine focused on factory and design automation issues.

### **Control Engineering Magazine**

44 Cook St.  
Denver, CO 80206-5191  
(303) 388-4511

Monthly publication focusing on industrial control subjects.

**DesignFax Magazine**

P.O. Box 21640

Eagan, MN 55121-0640

(216) 248-1125

Small magazine containing articles and information about control products intended for design engineers.

**Design News**

P.O. Box 173377

Denver, CO 80217

(303) 388-4511

Monthly magazine intended for design engineers. Many articles on power transmission and motion control.

**Instrumentation & Automation News**

P.O. Box 2005

Radnor, PA 19089

(215) 964-4000

This magazine contains various articles and product information for the industrial automation and control field.

**Machine Design Magazine**

1100 Superior Ave.

Cleveland, OH 44114-2543

(216) 696-7000

Monthly magazine for designers of machines and other products.

**Motion Control Magazine**

P.O. Box 7907

Wheaton, IL 60188

(708) 858-1888

This magazine contains a large variety of technical information including articles about stepper motors, servos and mechanical systems.

**Personal Engineering  
and Instrumentation News**

P.O. Box 430

Rye, NH 03870

(603) 427-1377

This publication has articles concerning laboratory automation, data acquisition and control.

**Scientific Computing  
& Automation Magazine**

P.O. Box 650

Morris Plains, NJ 07950-0650

(201) 292-5100

Monthly publication discussing control and automation topics.

# ***Component Suppliers***

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Many users of the MD-2 package are constructing some type of mechanical system which will require gears, bearings, pulleys and various other components. For this reason, the following list of part suppliers has been compiled. Most of the companies listed have catalogs which contain detailed part and technical information and can be obtained at little or no cost.

## **80/20 Inc.**

2570 Commercial Rd.  
Fort Wayne, IN 46809  
(219) 478-8020

Manufactures aluminum components used to create frames, benches and fixtures.

## **Allied Devices**

2365 Milburn Ave.  
Baldwin, NY 11510  
(516) 223-9100

Catalog contains over 55,000 items including gears, couplings, speed reducers, dials and shafts.

## **Bayside Controls**

20-02 Utopia Pkwy.  
Whitestone, NY 11357  
(800) 343-3353

Manufactures precision gear reducers for stepper and servo motors. Catalogs and technical information is available.

## **Boston Gear**

14 Hayard St.  
Quincy, MA 02171  
(800) 343-3352

A good selection of medium and large gears, pulleys, gear reducers and shaft components. A catalog is available.

## **Browning Manufacturing**

Maysville, KY 41056  
(606) 564-2011

Much like Boston Gear, this company carries mostly larger components such as gears and pulleys.

## **EFD**

East Providence, R.I. 02914  
(401) 434-1680

Manufactures hand-held dispensing devices used to apply adhesive, solvents and other fluids.

**Foredom**

Bethel, CT 06801

(203) 792-8622

Manufactures hand-held rotary power tools and accessories.

**Igus Inc.**

P.O. Box 14349

East Providence, R.I. 02914

(401) 438-2200

Manufactures cable and hose carriers.

**Helical Products**

901 W. McCoy Lane

Santa Maria, CA 93456

(805) 928-3851

Manufactures precision shaft couplers.

**Lovejoy, Inc.**

2655 Wisconsin Ave.

Downers Grove, IL 60515

(708) 852-0500

Manufactures a variety of products including shaft couplers.

**Martin Sprocket and Gear**

P.O. Box 888

Arlington, TX 76004

(817) 465-6377

Stocks medium to large sprockets, gears and other components.

**Nordex**

50 Newtown Rd.

Danbury, CT 06810-6216

(203) 792-9050

Nordex is an excellent source for small gears, bearings, shafts and various other precision components at a reasonable cost.

**PIC Design**

P.O. Box 1004

Middlebury, CT 06762

(203) 758-8272

PIC Design is also known as Precision Industrial Components and stocks a wide variety of gears, pulleys, bearings and lead screw assemblies.

**Plastock**

Three Oak Rd.

Fairfield, NJ 07006

(203) 928-7911

Manufactures plastic gears and pulleys.

**SAVA Industries**

70 Riverdale Rd.  
Riverdale, NJ 07457  
(201) 835-0882  
Manufactures cables and pulleys.

**SECS**

520 Homestead Ave.  
Mt. Vernon, NY 10550  
(914) 667-5600  
A good source for gears, handles, dials and timing pulleys.

**Seitz**

Torrington Industrial Lane  
Mt. Vernon, NY 10550  
(203) 489-0476  
Carries small gears, bearings, pulleys and other precision components.

**Small Parts**

6891 N.E. 3rd Ave.  
P.O. Box 381736  
Miami, FL 33238-1736  
(305) 751-0856  
This company stocks a broad range of precision parts such as screws, tubing, and tools.

**Solidur Plastics**

200 Industrial Dr.  
Delmont, PA 15626  
(800) 343-0444  
Manufactures gears and other parts from plastic.

**Stock Drive Products**

2101 Jericho Turnpike  
New Hyde Park, NY 11040  
(516) 328-0200  
This company probably has the broadest line of precision mechanical components available including gears, pulleys, bearings and hardware. Metric sizes are also available. Several catalogs and technical books are available.

**Winfred M. Berg**

499 Ocean Ave.  
East Rockaway, NY 11518  
(516) 599-5010  
The Berg catalog contains gears, bearings and large assortment of unusual belts and pulley systems.

# Troubleshooting

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The following list describes the most common problems and their remedies. Repairs should be left to qualified persons.

**Problem:** Power light does not light.

**Remedy:** The MD-2 driver is probably not getting power. Check the power cord and fuse. If the fuse is blown, replace with one of the exact same type and value. If the fuse blows a second time, repairs must be made. If a battery is being used, make sure the voltage is correct at the terminal strip during operation. Make sure the power jumper is removed when using a battery and connected when using AC.

**Problem:** Power light turns on but the motor lights do not and the motors do not move.

**Remedy:** The motors are not being turned on by the control computer. Check the cable connecting the MD-2 to the computer. If custom software is being used, return to the MD-2 program to verify operation. Check the port address in the software.

**Problem:** Motor lights turn on but the motors do not move.

**Remedy:** Check the motor cables for breaks or cuts. Swapping cables and motors using the process of elimination will determine which component is defective. Return to non-custom software to eliminate the possibility of software problems. Also, check the motor speed values since giving step pulses too fast will not allow the motors to move.

**Problem:** Activating the 'HOME' switches does not turn on the switch lights.

**Remedy:** Check the wiring of the switches and the motor cables. The switch must drive the input to ground to be detected.

**Problem:** Activating the switches turns on the lights but the software does not recognize them.

**Remedy:** Check the cable that connects the MD-2 to the computer. Check for software errors and verify the port address.

**Problem:** The heat generated by the motors and/or driver must be minimized.

**Remedy:** Motor and driver heating is normal and occurs mostly during standstill. The motors can be mounted to a metal plate to help dissipate the heat and a fan can be located near the MD-2 driver enclosure to carry away the heat. The software can be configured to de-energize the motor coils during standstill when holding torque is not required. This will greatly reduce motor and driver heating.

**Problem:** As the load increases the motor sometimes misses steps causing inaccurate positioning.

**Remedy:** The available torque of a stepper motor decreases as the speed increases. Decrease the speed of the motor to increase the available torque which will reduce the possibility of lost steps. The motor must have enough torque to withstand all momentary requirements.

**Problem:** The motors move but the speed is not smooth.

**Remedy:** If another program is consuming the computer while motors are moving, erratic motion will result. Disable any TSR (Terminate and stay resident) programs or other programs that work in the background.

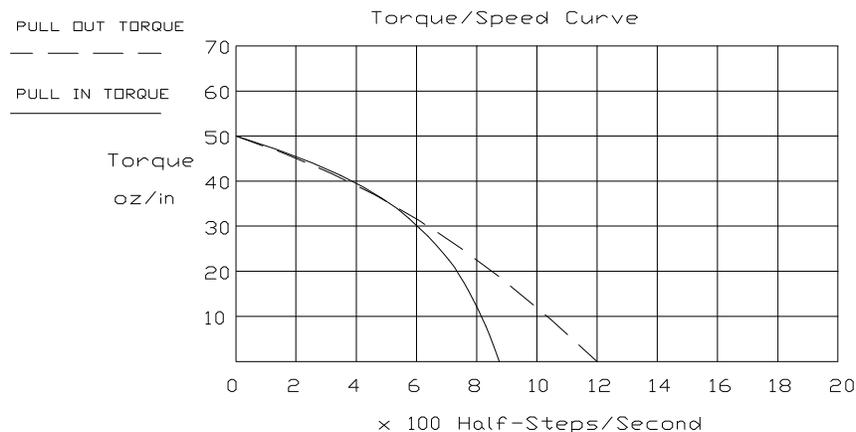
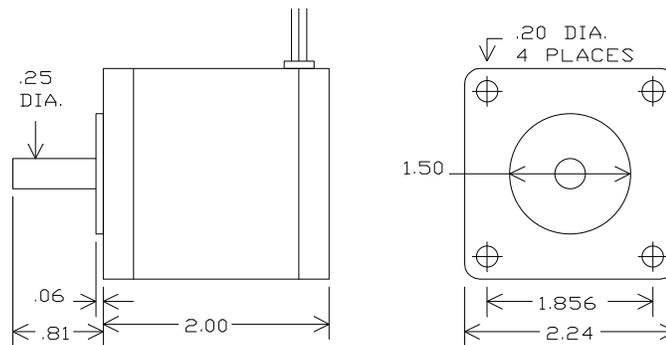
# MD-2 Specifications

## Driver Unit

Size: 8.5" x 3" x 6.5"  
 Weight: 7 lbs.  
 Lamps: Power, motor and switch status.  
 Power Input: 115 VAC, 50-60 Hz @ 1 Amp  
 or 12 VDC @ 5 amps.  
 Motor Port: 9 pin D-sub female.  
 CPU Port: 36 pin centronics female.  
 Drive Type: Unipolar L/3R resistance limited.

## Motors

Size: Nema frame #23, 2.25" diameter, 2.25" long,  
 Shaft: .25" diameter, .75" long.  
 Mounting: 4 holes, .2" diameter, 1.856" square pattern.  
 Weight: 21 ounces.  
 Windings: Unipolar, 5.1 volt, 1 amp  
 Connector: 9 pin male D-sub.  
 Cable: 9 conductor, 22 AWG.  
 Full step: 1.8 degrees, +/- 5% accuracy.  
 Half step: .9 degrees, +/- 5% accuracy.  
 Detent Torque: 1 oz/in.  
 Holding Torque: 50 oz/in.



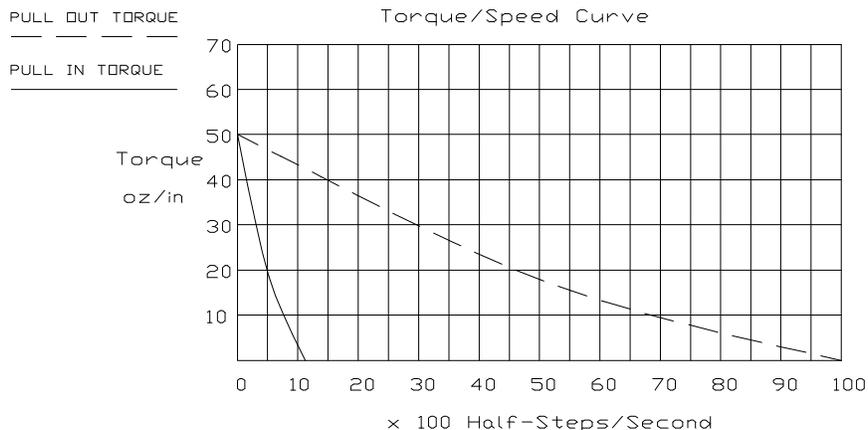
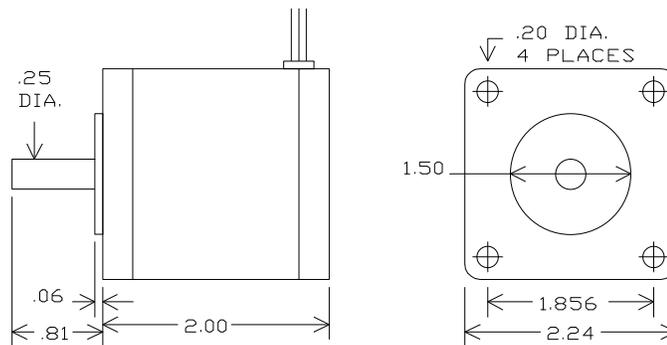
# MD-2a Specifications

## Driver Unit

Size: 8.5" x 3" x 6.5"  
 Weight: 7 lbs.  
 Lamps: Power, motor and switch status.  
 Power Input: 115 VAC, 50-60 Hz @ 1 Amp  
 or 28 VDC @ 5 amps.  
 Motor Port: 9 pin D-sub female.  
 CPU Port: 36 pin centronics female.  
 Drive Type: Unipolar chopper.

## Motors

Size: Nema frame #23, 2.25" diameter, 2.25" long,  
 Shaft: .25" diameter, .75" long.  
 Mounting: 4 holes, .2" diameter, 1.856" square pattern.  
 Weight: 21 ounces.  
 Windings: Unipolar, 5.1 volt, 1 amp  
 Connector: 9 pin male D-sub.  
 Cable: 9 conductor, 22 AWG.  
 Full step: 1.8 degrees, +/- 5% accuracy.  
 Half step: .9 degrees, +/- 5% accuracy.  
 Detent Torque: 1 oz/in.  
 Holding Torque: 50 oz/in.



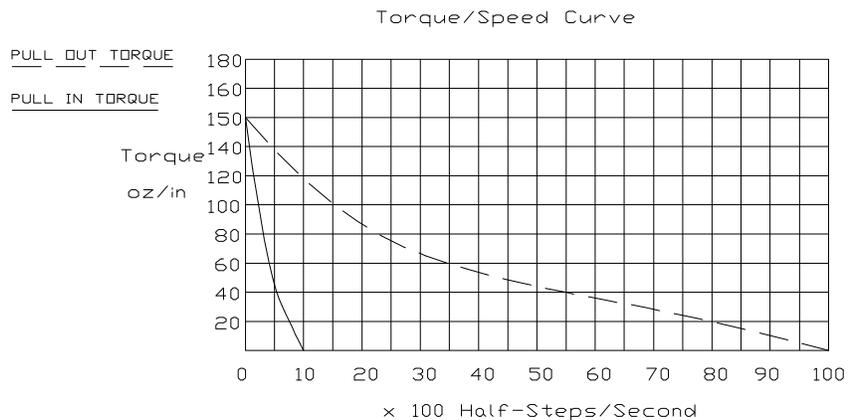
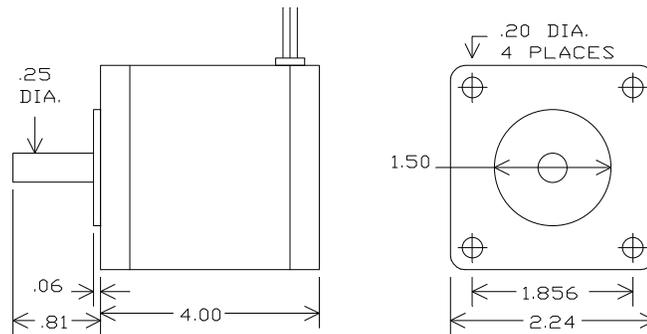
# MD-2b Specifications

## Driver Unit

Size: 8.5" x 3" x 6.5"  
 Weight: 10 lbs.  
 Lamps: Power, motor and switch status.  
 Power Input: 115 VAC, 50-60 Hz @ 1 Amp  
 or 28 VDC @ 13 amps.  
 Motor Port: 9 pin Molex female.  
 CPU Port: 36 pin centronics female.  
 Drive Type: Unipolar chopper.

## Motors

Size: Nema frame #23, 2.25" diameter, 4" long,  
 Shaft: .25" diameter, .75" long.  
 Mounting: 4 holes, .2" diameter, 1.856" square pattern.  
 Weight: 48 ounces.  
 Windings: Unipolar, 3.4 volt, 2.9 amp  
 Connector: 9 pin male Molex.  
 Cable: 9 conductor, 18 AWG.  
 Full step: 1.8 degrees, +/- 5% accuracy.  
 Half step: .9 degrees, +/- 5% accuracy.  
 Detent Torque: 1 oz/in.  
 Holding Torque: 150 oz/in.



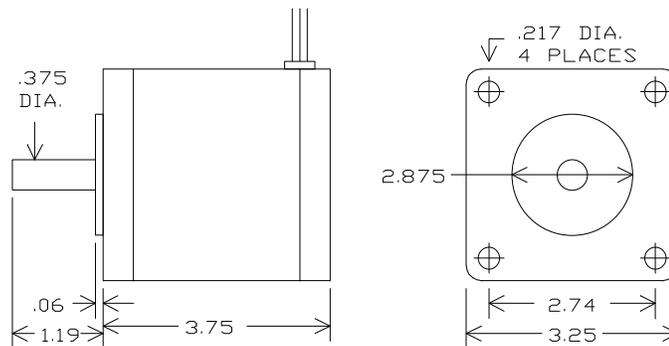
# MD-2c Specifications

## Driver Unit

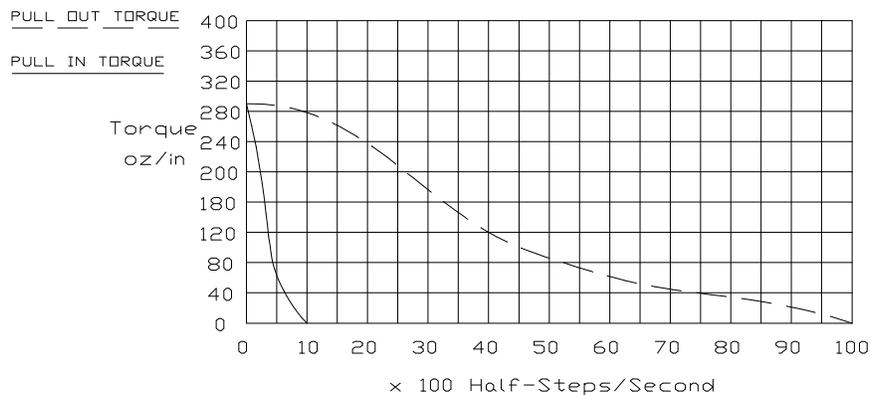
Size: 8.5" x 3" x 6.5"  
 Weight: 10 lbs.  
 Lamps: Power, motor and switch status.  
 Power Input: 115 VAC, 50-60 Hz @ 1 Amp  
 or 28 VDC @ 17 amps.  
 Motor Port: 9 pin Molex female.  
 CPU Port: 36 pin centronics female.  
 Drive Type: Unipolar chopper.

## Motors

Size: Nema frame #34, 3.4" diameter, 3.75" long,  
 Shaft: .375" diameter, 1.25" long.  
 Mounting: 4 holes, .2" diameter, 2.739" square pattern.  
 Weight: 80 ounces.  
 Windings: Unipolar, 3 volt, 4 amp  
 Connector: 9 pin male Molex.  
 Cable: 9 conductor, 18 AWG.  
 Full step: 1.8 degrees, +/- 5% accuracy.  
 Half step: .9 degrees, +/- 5% accuracy.  
 Detent Torque: 1 oz/in.  
 Holding Torque: 300 oz/in.



Torque/Speed Curve



# **Warranty Information**

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ARRICK ROBOTICS warrants this product to be in good working order for a period of one (1) year from the date of purchase. Should this product fail to be in good working order at any time during this period, ARRICK ROBOTICS will, at its option, repair or replace the product at no additional charge except as set forth below. This limited warranty does not include service to repair damage to the product resulting from accident, disaster, misuse, abuse, or modification of the product. To obtain warranty service, send the product along with proof of purchase in its original packaging to:

ARRICK ROBOTICS  
Attn: Repair Dept.  
10768 Technology Dr. CR2335  
Tyler, TX 75707

You agree to prepay shipping charges and to insure the product or assume the risk of loss or damage in transit. All express or implied warranties for this product including the warranties of merchantability and fitness for a particular purpose are limited in duration to a period of one (1) year from the date of purchase, and no warranties, whether expressed or implied, will apply after this period.

If this product is not in good working order as warranted above, your sole remedy shall be repair or replacement as provided above. In no event will ARRICK ROBOTICS be liable to you for damages, including any lost profits, lost savings or other incidental or consequential damages arising out of the use of or inability to use this product.

Some states do not allow limitations on how long an implied warranty lasts, so the above limitations may not apply to you. Some states do not allow the exclusion or limitation of incidental or consequential damages for consumer products, so the above limitations may not apply to you. This warranty gives you specific legal rights and you may also have other rights which may vary from state to state.