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## Sizing a Rotary Axis Using Motion Analyzer

ALLEN-BRADLEY • ROCKWELL SOFTWARE

**Rockwell**  
**Automation**



# **Sizing a Rotary Axis Using Motion Analyzer: Hands-On Lab**

**Training Lab Manual**

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# Sizing a Rotary Axis

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## About This Hands-On Lab

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This lab uses Rockwell Automation's motion sizing software, Motion Analyzer, for the purpose of sizing and selecting a servo motor and drive for a rotary axis. The software allows you to enter information about the moving axis of your machine (the load and the actuator that is moving it) as well as your required move or cycle profile in order to select the appropriate servo motor and drive combination.

The following sections explain what you'll be doing in this lab session, and what you will need to do to complete the hands-on exercises.

### What You Will Accomplish In This Lab

As you complete the exercises in this hands-on session, you will:

- Learn how to use Motion Analyzer software in rotary applications
- Learn what type of information is required by the software

### Who Should Complete This Lab

This hands-on lab is intended for individuals who:

- Would like to learn more about sizing rotary motion systems
- Would like to learn more about using Motion Analyzer software

## Lab Materials

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For this Hands-On lab, we have provided you with the following materials that will allow you to complete the labs in this workbook.

### Hardware

This hands-on lab uses no hardware.

### Software

This hands-on lab uses the following software:

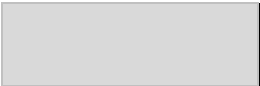
- Motion Analyzer V4.4 (available for download at [www.ab.com/motion](http://www.ab.com/motion))

### Lab Files

- This hands-on lab requires no additional files.

## Document Conventions

Throughout this workbook, we have used the following conventions to help guide you through the lab materials.

This style or symbol:	Indicates:
Words shown in bold italics (e.g., <i>RSLogix 5000</i> or <i>OK</i> )	Any item or button that you must click on, or a menu name from which you must choose an option or command. This will be an actual name of an item that you see on your screen or in an example.
Words shown in bold italics, enclosed in single quotes (e.g., ' <i>Controller1</i> ')	An item that you must type in the specified field. This is information that you must supply based on your application (e.g., a variable).  <b>Note:</b> When you type the text in the field, remember that you do not need to type the quotes; simply type the words that are contained within them (e.g., Controller1).
	The text that appears inside of this gray box is supplemental information regarding the lab materials, but not information that is required reading in order for you to complete the lab exercises. The text that follows this symbol may provide you with helpful hints that can make it easier for you to use this product. Most often, authors use this "Tip Text" style for important information they want their students to see.

**Note:** If the mouse button is not specified in the text, you should click on the left mouse button.

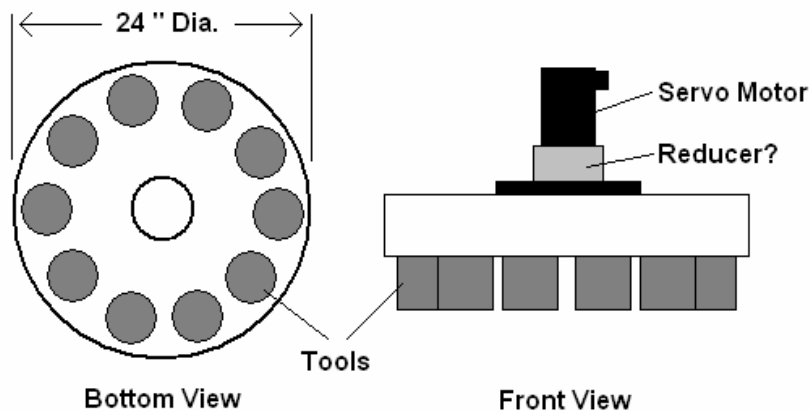


Fig.1 Typical Rotary Tool Changer



# Lab 1: Sizing a Tool Changer (20 minutes)

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A tool changer (see Fig. 1) will be the source of data for entry into Motion Analyzer. Tool changers are used in the machining industry so that the machine operator can choose between a wide variety of cutting, drilling and tapping tools on demand. Our customer is only requesting a simple stand-alone axis of motion for the addition of the tool changer. We'll assume that the CNC (most likely) machine is already built and running.

## About This Lab

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In this lab, we'll gather and enter the mechanical details and the desired cycle profile of the tool changer into Motion Analyzer and select a Servo Motor and Drive for the application. You will:

- Open Motion Analyzer and set the default values to suit your needs
- Create a new application
- Enter the required data for the tool changer application
- Select a motor and drive
- Investigate any additional shunt requirements

Follow the steps below to complete Lab Section 1.

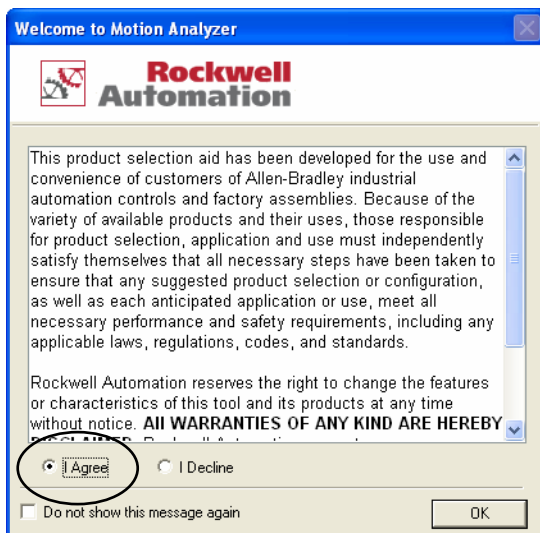
## Open Motion Analyzer Software

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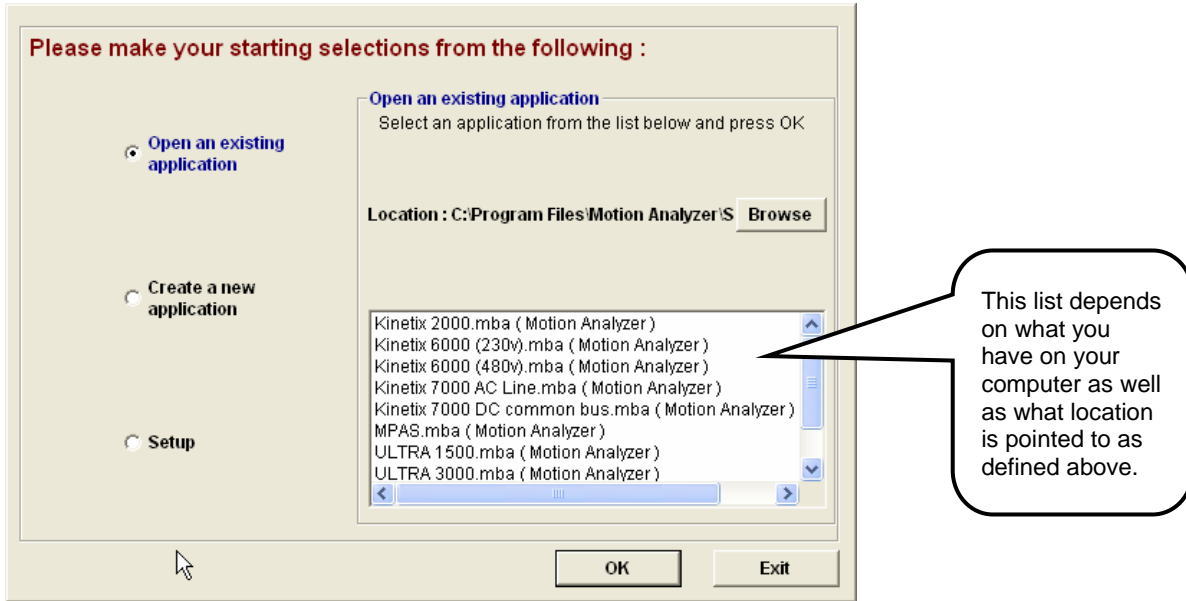
1. **Open Motion Analyzer** sizing software by double-clicking on the shortcut in the upper right corner of the desktop.



2. After reading the terms, select **I Agree** and press the **OK** button.



3. A selection screen will open:

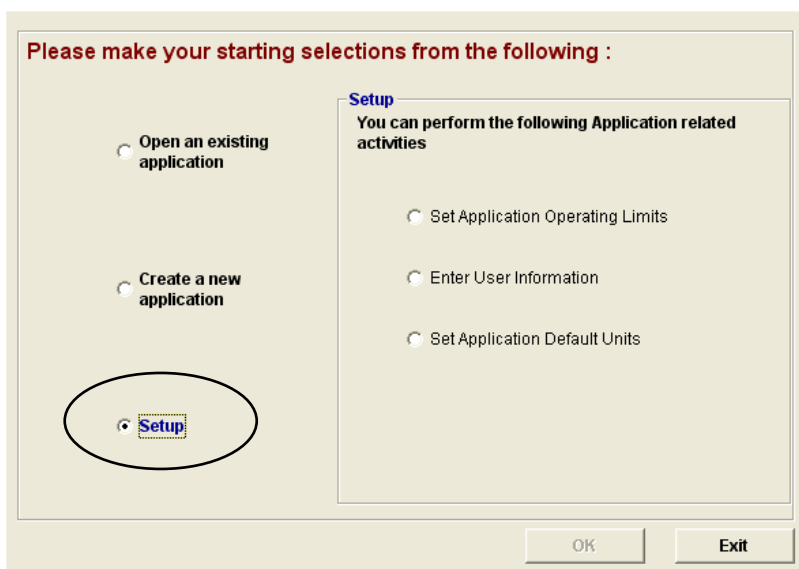


4. Your choices are defined as follows:

- **Open an existing application** – Open any file created in the listed directory. Note: You will see the listing of any file created in the default directory. To look into another directory simply use the **browse** function.
- **Create a new application** – Start a new Motion Analyzer file.
- **Setup** – For the new application file, change the user information, units of measurement and operating limits.

## Setting up User Defaults

5. Click on the **Setup** button and notice that there are (3) selections available.



## 6. Select **Set Application Operating Limits**.

The screenshot shows a software dialog box titled "Options" with three tabs: "Operating Limits", "User Information", and "Units of Measure". The "Operating Limits" tab is active. It is divided into three sections: "Motor", "Drive", and "Gearbox". Each section contains several variables, each with a text input field set to the value "80".

Section	Variable	Value
Motor	Motor Capacity	80
	Peak Velocity	80
	Peak Torque	80
	Inertia Ratio (Max)	80
Drive	Drive Capacity	80
	Average Current	80
	Peak Current	80
	Bus Volts	80
Gearbox	Shunt Power	80
	Peak Input Velocity	80
	RMS Torque	80
	Peak Torque	80
	Nominal Speed	80

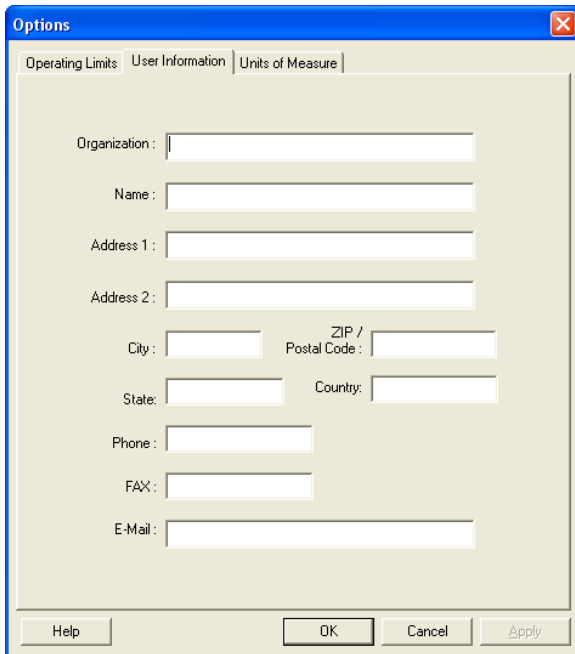
At the bottom of the dialog, there is a note: "All values are percentages of the rated values .". Below the note are four buttons: "Help", "OK", "Cancel", and "Apply".

The automatic selection process is affected by the limits entered in this table. Each of the motor/amplifier/gearbox variables listed in the table is a *percentage of the rated values* listed. The idea here is to choose operating limits based on the reliability of the data that is entered. Think of this page or table as a *safety factor* when selecting a combination. Keep the numbers as shown.

If entered data (load, transmission, profile and environment information) is absolutely reliable, these limits *could* all be set to 100% utilization but we all know that some information may not be totally accurate or we may encounter some unknowns during the implementation of the application.

- "Peak Velocity" and "Bus Volts" are the most easily defined so keep these numbers at 90% or higher.
- "Peak Torque", "Peak Current" and "Average Current" are less reliable so keep these numbers at 80%.
- "Winding Temperature" is the most sensitive to errors so 80 % would be normal.

7. Select the **User Information** tab. Your information may be entered here so that your name, email, phone number and company name will automatically appear on any reports. If you are preparing this system for another user (your customer, for instance), another screen will prompt you for their information when a system report is generated.

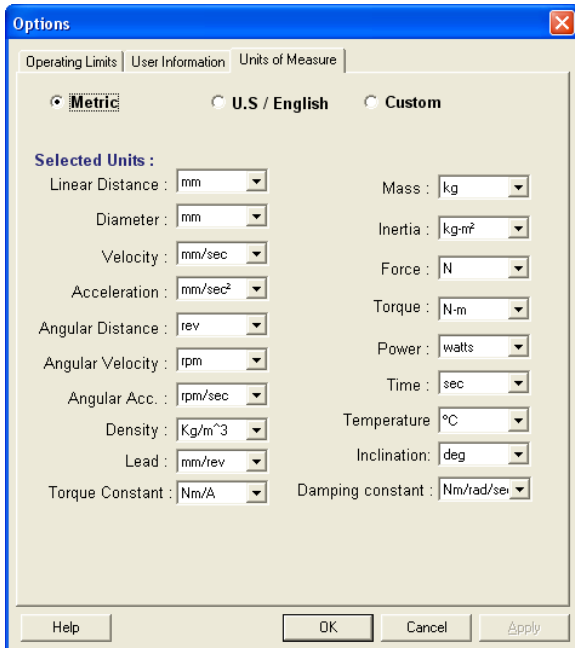


The screenshot shows the 'Options' dialog box with the 'User Information' tab selected. The dialog has three tabs: 'Operating Limits', 'User Information', and 'Units of Measure'. The 'User Information' tab contains the following fields:

- Organization: [Text Box]
- Name: [Text Box]
- Address 1: [Text Box]
- Address 2: [Text Box]
- City: [Text Box] ZIP / Postal Code: [Text Box]
- State: [Text Box] Country: [Text Box]
- Phone: [Text Box]
- FAX: [Text Box]
- E-Mail: [Text Box]

At the bottom of the dialog are buttons for 'Help', 'OK', 'Cancel', and 'Apply'.

8. Select the **Units of Measure** tab.

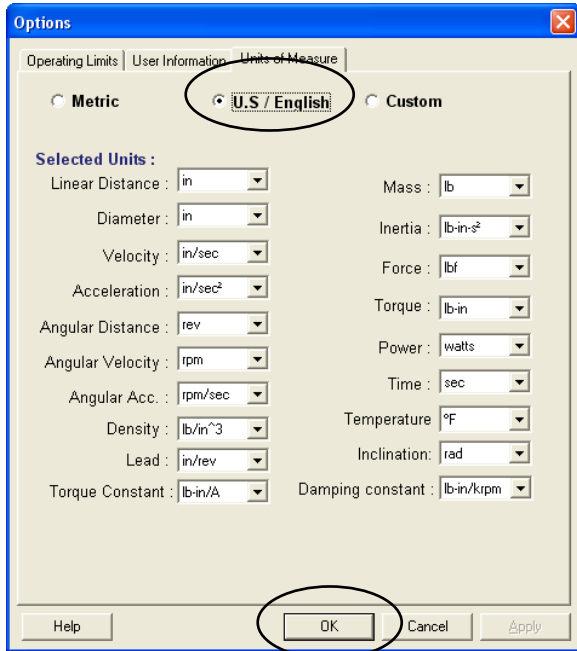


The screenshot shows the 'Options' dialog box with the 'Units of Measure' tab selected. The dialog has three tabs: 'Operating Limits', 'User Information', and 'Units of Measure'. The 'Units of Measure' tab contains the following options:

- Radio buttons for **Metric** (selected), **U.S / English**, and **Custom**.
- Selected Units:**
  - Linear Distance: [mm]
  - Diameter: [mm]
  - Velocity: [mm/sec]
  - Acceleration: [mm/sec<sup>2</sup>]
  - Angular Distance: [rev]
  - Angular Velocity: [rpm]
  - Angular Acc.: [rpm/sec]
  - Density: [kg/m<sup>3</sup>]
  - Lead: [mm/rev]
  - Torque Constant: [Nm/A]
  - Mass: [kg]
  - Inertia: [kg-m<sup>2</sup>]
  - Force: [N]
  - Torque: [N-m]
  - Power: [watts]
  - Time: [sec]
  - Temperature: [°C]
  - Inclination: [deg]
  - Damping constant: [Nm/rad/sec]

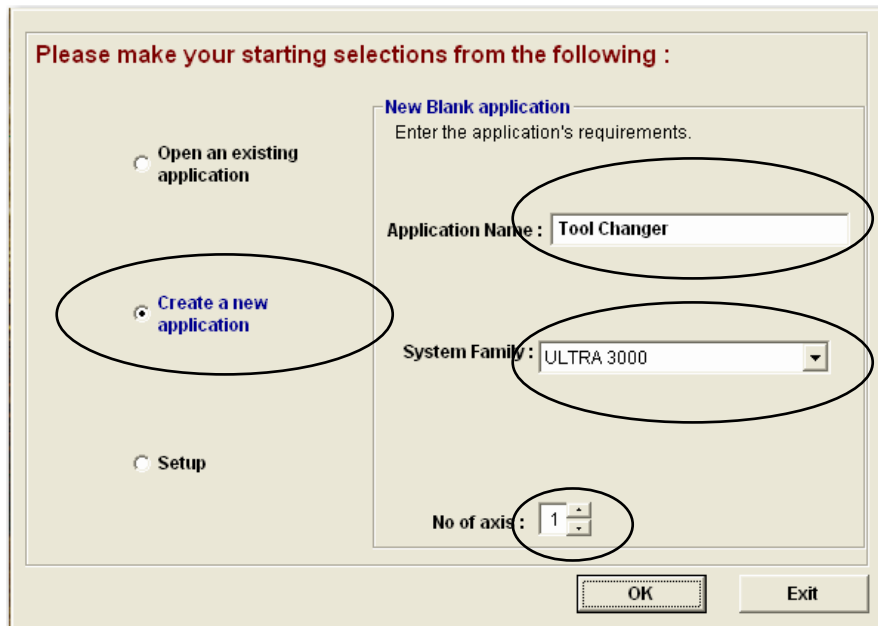
At the bottom of the dialog are buttons for 'Help', 'OK', 'Cancel', and 'Apply'.

9. Change the default units to **U.S./English** and select **OK** to save and exit.

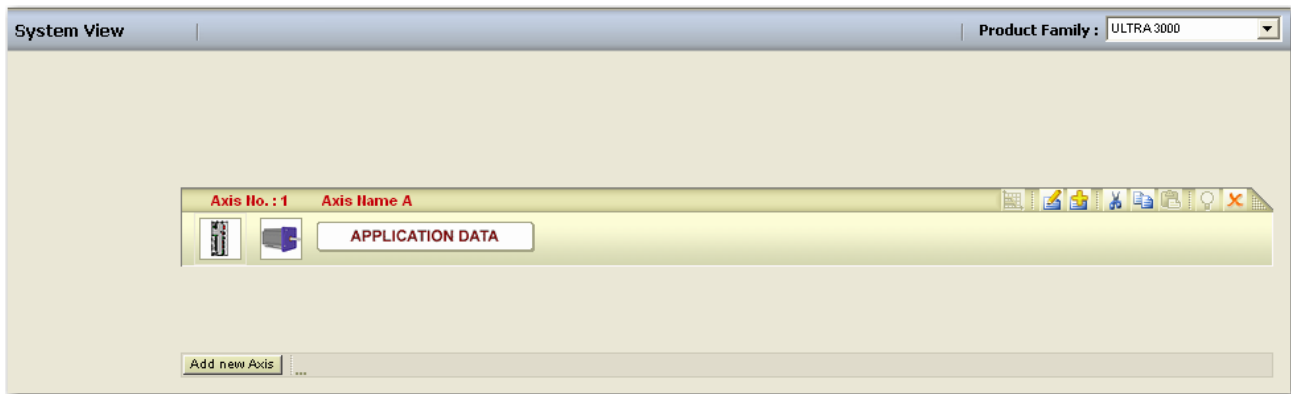


## Creating a New Application

10. Select the **Create a new application** radio button. Enter “**Tool Changer**” for the Application Name, **Ultra 3000** for the System Family and increment the No. of Axis to “**1**.” Select **OK**.



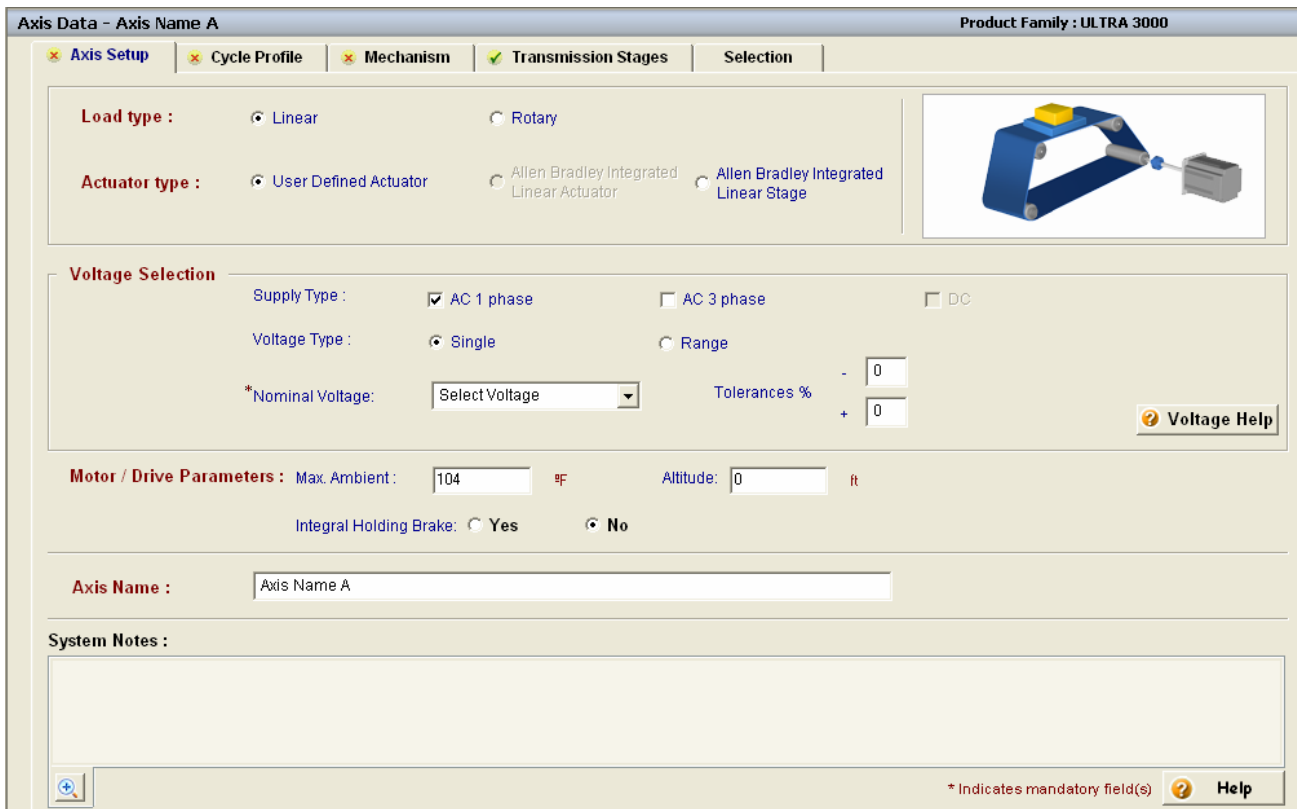
11. The **System View** screen displays. It identifies our single axis system. At this point, minimal information is displayed. As we proceed with our sizing exercise, additional information will populate this screen. At the end of the sizing exercise, information such as motor and drive part numbers, actuator types, etc. will be viewable from this screen.



12. To begin entering data for an axis, click on the **Application Data** button.



13. The **Axis Data** page displays basic setup options for the axis.



On this page, you choose whether your axis is linear or rotary, and whether the axis is built from user-provided components or one of Rockwell Automation's MP-Series Integrated Actuators. The voltage (or range of voltages) that will be provided to the drives is defined here, and you can enter a typical ambient temperature for the motor's operating environment. If your axis requires a (factory only) holding brake, you can make this selection here. Finally, this is where you can give the axis a meaningful name.

14. At the bottom of the screen, click on the area marked **System Notes**. This is where you can enter important information about the system, or keep track of assumptions that were made in the sizing process. This data will be printed on the system report and it will remind you that these assumptions need verified. It is not uncommon to have missing data during this process.

**System Notes :**

Keep good notes here!

15. Let's get started entering information about the belt indexer axis.

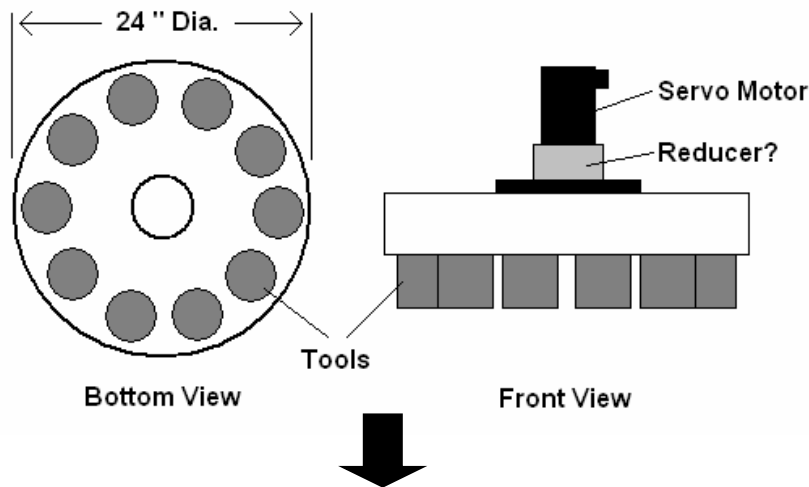
There are (7) steps to sizing a motion application in Motion Analyzer. They are:

- (1) Determine application **preferences**
- (2) Specify the machine's **cycle profile**, or worst case move
- (3) Specify **load type**
- (4) Specify **actuator type**
- (5) Specify **transmission stage(s)**
- (6) Search for a suitable **motor/drive combination** for the application
- (7) Select **shunt** (if required) and system module (for Kinetix 2000/6000 drives)

Let's follow the (7) steps outlined above to enter our application data.

## Entering the Tool Changer Information

16. Here is the data that was provided for the **tool changer** axis:



- Horizontal tool changer weight = 100 lbs. (total including tools)
- 24" diameter
- Move from 1 tool to next in (1) second, dwell (1.0) second.
- 10 tools maximum

17. On the **Axis Setup** tab, change the **Load Type** to **Rotary**, since this is not a linear system.

18. Our plant has 460Vac, so **uncheck** the **AC 1 phase box** and **check** the **AC 3 Phase box**. Use the drop-down to select **460** for the **nominal voltage**.

19. Finally, give the axis the name **Tool Changer**.

Axis Setup | Cycle Profile | Mechanism | Transmission Stages | Selection

Load type :  Linear  Rotary

Actuator type :  User Defined Actuator  Allen Bradley Integrated Linear Actuator  Allen Bradley Integrated Linear Stage

Voltage Selection

Supply Type :  AC 1 phase  AC 3 phase  DC

Voltage Type :  Single  Range

\*Nominal Voltage : 460 Tolerances % - 10 + 10

Motor / Drive Parameters : Max. Ambient : 104 °F Altitude : 0 ft

Integral Holding Brake :  Yes  No

Axis Name : Tool Changer



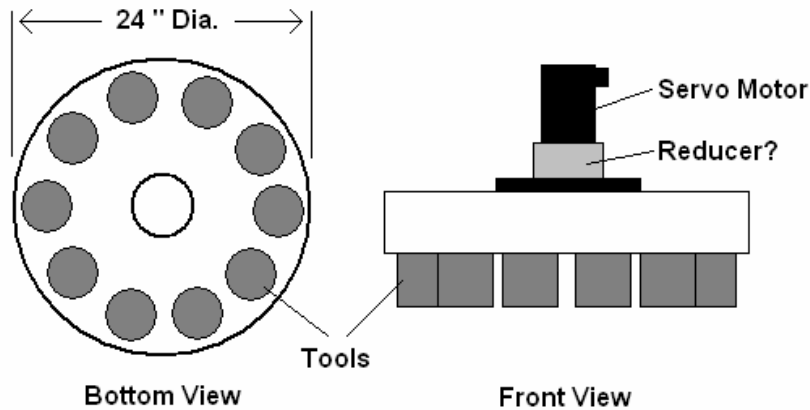
20. The tabs across the top lead you through entering the required data. The *green check mark* means that you have completed a tab and the *red "x"* indicates that more data is needed. Move on to the **Cycle Profile** tab.



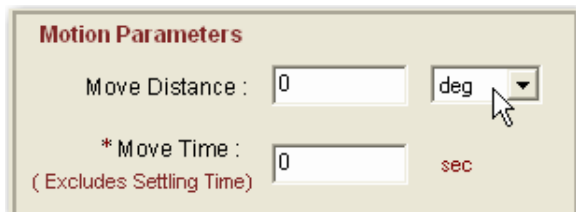
21. Our required cycle profile is a simple point to point move (move 1 tool in 1 sec. and dwell for 1 sec), so we are going to use the **Indexing** move profile. If the profile had more moves, changes in speeds or changes in loads/forces, we would need to use the MultiSegment entry. Click on the **Cycle Profile Data** button.



For our rotary axis, moving from one tool to the next with (10) tool "holders" means we are moving **36 degrees** ( $360 \text{ degrees} / 10 \text{ tools}$ ) between tools.

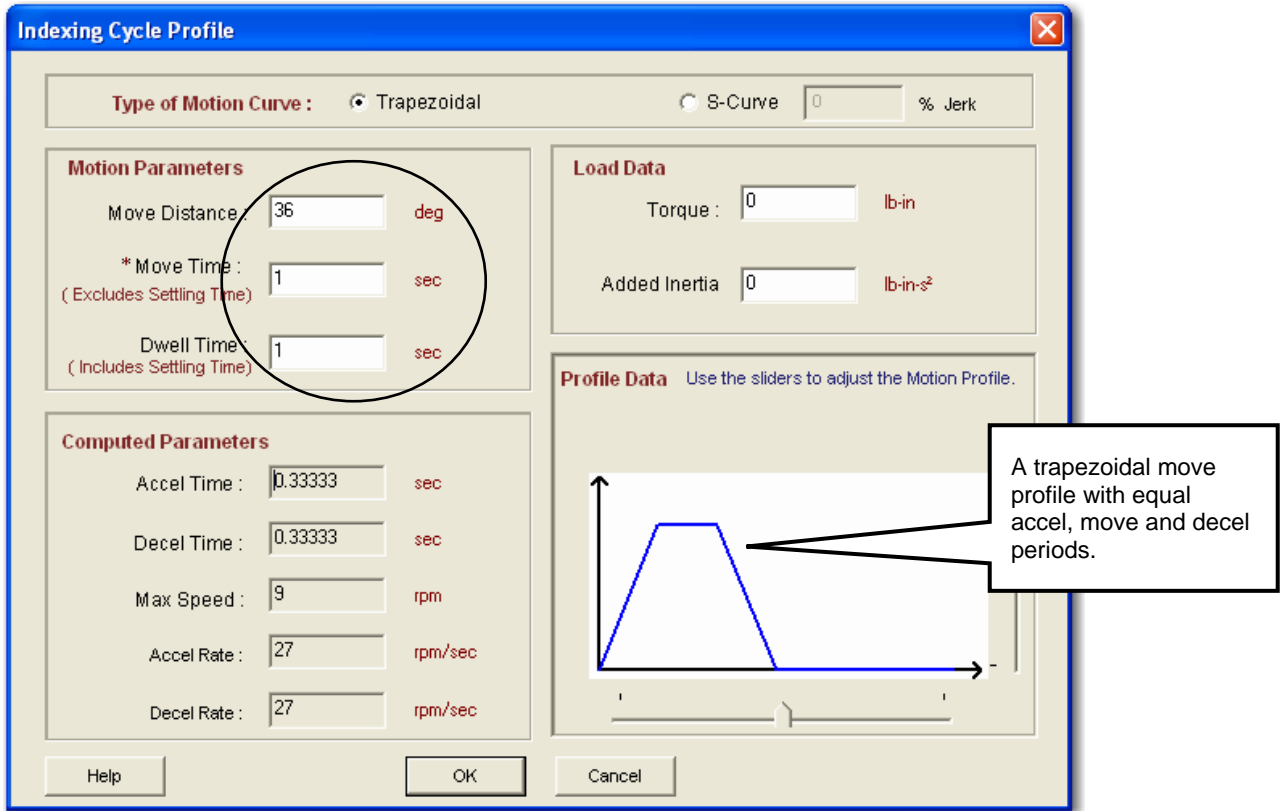


22. Use the drop down beside the **Move Distance** value to change the units to **deg**. You should change the units before entering the value, or it will be converted.



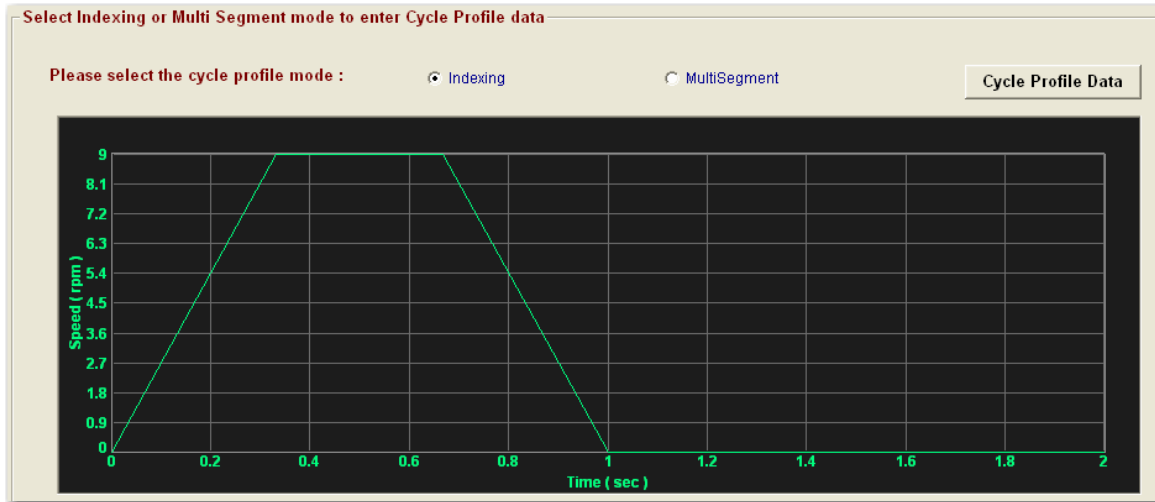
23. Simply enter the **cycle profile** as provided. We could have entered the Load Data here, but there is a better place on the Mechanism tab for this information. We assume a **trapezoidal** move profile with equal acceleration, move and deceleration times (the 1/3 rule). Notice how the **accel** and **decel** values have been calculated for you, as well as the **maximum velocity** required to achieve our move profile.

24. Press **OK** when complete.



It is important to include your *dwell* time in the cycle profile, because the software assumes that the move is performed over and over with no stopping. The dwell tells the software to factor in resting periods for the thermal modeling of the motor and drive. You may end up with a motor and drive larger than you need if you omit this dwell period.

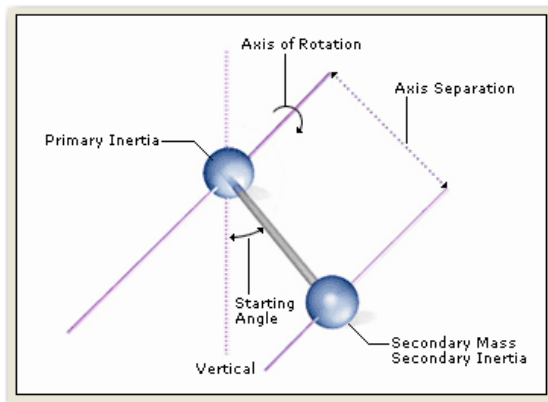
25. The **cycle profile** should appear as shown.



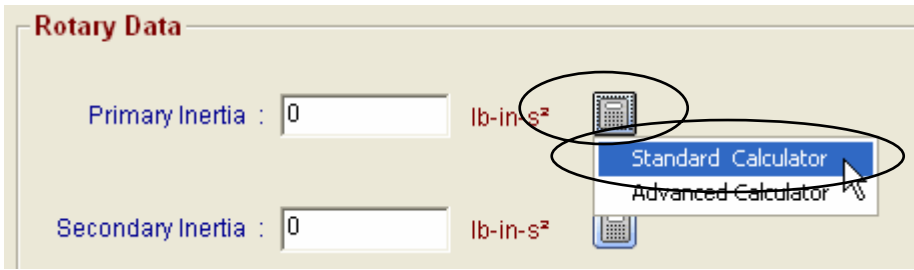
26. Click on the **Mechanism** tab to continue.

The screenshot shows the "Mechanism" tab selected in a software interface. The "Rotary Data" section contains several input fields: "Primary Inertia" (0 lb-in-s<sup>2</sup>), "Secondary Inertia" (0 lb-in-s<sup>2</sup>), "Secondary Mass" (0 lb), "Losses" (0 lb-in), "Starting Angle" (0 rad), and "Axis Separation" (0 in). To the right is a diagram of a rotary axis mechanism. The diagram shows a vertical axis of rotation with a primary inertia mass. A secondary mass is attached to the axis at an angle, with labels for "Starting Angle", "Secondary Mass", and "Secondary Inertia". The distance between the two axes is labeled "Axis Separation".

This tab includes a helpful diagram that explain the keywords used in entering the required information for your rotary axis.



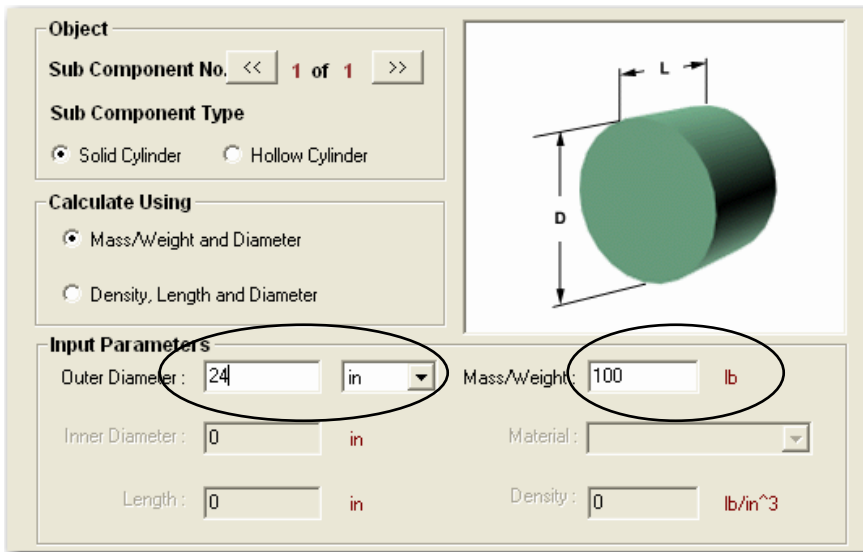
27. Motion Analyzer includes helpful inertia calculators to aid in the process of finding the total inertia of simple or complex rotating objects. Click on the **inertia calculator** button for the **Primary Inertia** section. Select the **Standard Calculator** option.



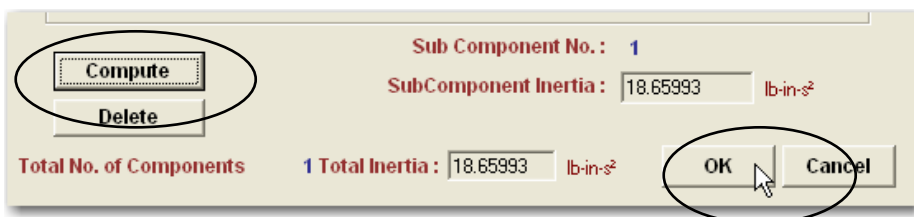
The Standard Calculator tool is designed to work with *balanced rotary systems* (where the axis of rotation is the same as the center of gravity) and the Advanced Calculator is for *unbalanced rotary systems* (where there is a separation between the axis of rotation and the center of gravity). We'll assume our system is balanced.

We can also assume that the rotary tool changer is virtually solid, and most likely it is. This works if the weight is distributed fairly evenly across the object.

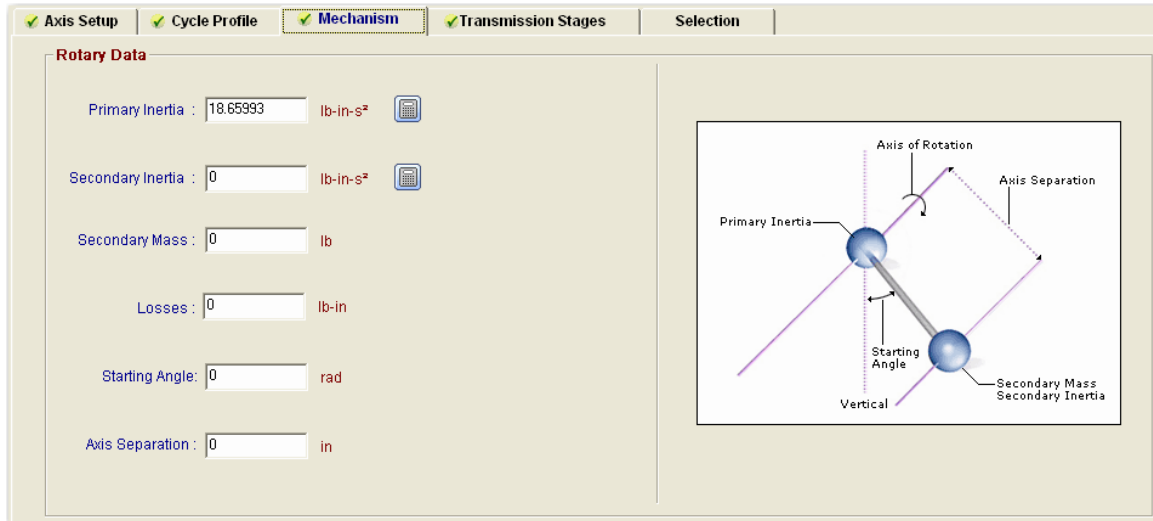
28. Enter the **24"** diameter given for the **Outer Diameter** value and put the **100 lbs** under the **Mass/Weight** value.



29. Press **Compute** to calculate the inertia. If the system had had several components of different sizes, weights or materials, we could have broken it into several sub components. Press **OK** when done.



30. Your system should be modeled as follows:



We don't have any belt reduction, spear gears or couplings to consider, so we can *skip* the Transmission tab for this application.

## Finding a Valid Solution

31. We have finished entering the application data and now we can select a motor and drive. Move to the **Selection** tab.



This tab allows us to set our *selection preferences*. We can specify whether to include or exclude a gearbox. We can specify which motor families to include, even down to the frame size of the motor. By default, the MPL Series motors are chosen. These motors are fine for most applications.

32. Press the button to **Show the Solutions within the Maximum Inertia Ratio** (load to motor mismatch). We will exclude solutions above 10:1 in order to insure system stability. This is a concern when trying to position accurately.

Axis Setup Cycle Profile Mechanism Transmission Stages Selection

Motor Type :  Motor  Motor with Gearbox  Allen Bradley Integrated Gearmotor

**Gear Parameters**

Manufacturer : Alpha +

Configuration : ALL

Series : SP

Frames : All (080,075,10...

**Motor Parameters**

Max. Inertia Ratio : 10

Show All Solutions  Show the Solutions within the Max. Inertia Ratio

Series : MPL-B

Frames : All (150,200,300,400...

**Database Search Options :**  Full  User Marked

Please choose the mode of selection :  Step by step

	Manual	Automatic	
Motor	<input type="radio"/>	<input checked="" type="radio"/>	<input type="button" value="Select"/> Current Selection :
Drive	<input type="radio"/>	<input checked="" type="radio"/>	<input type="button" value="Select"/> Current Selection :

Select Manual to choose your Components.  
Select Automatic to have Motion Analyzer select for you.

33. If you had special requirements for your motor (food grade or wash down environment or if you just had a size and space restriction), you could direct Motion Analyzer to choose from a different set of motors. Click on the **Change** button next to the motor **Series**.

Axis Setup Cycle Profile Mechanism Transmission Stages Selection

Motor Type :  Motor  Motor with Gearbox  Allen Bradley Integrated Gearmotor

**Gear Parameters**

Manufacturer : Alpha +

Configuration : ALL

Series : SP

Frames : All (060,075,10...

**Motor Parameters**

Max. Inertia Ratio : 10

Show All Solutions  Show the Solutions within the Max. Inertia Ratio

Series : MPL-B

Frames : All (150,200,300,400...

**Database Search Options :**  Full  User Marked

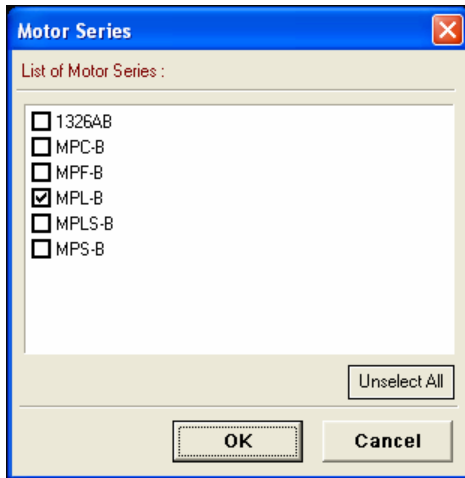
Please choose the mode of selection :

	Manual	Automatic	
Motor	<input type="radio"/>	<input checked="" type="radio"/>	<input type="button" value="Select"/> Current Selection :
Drive	<input type="radio"/>	<input checked="" type="radio"/>	<input type="button" value="Select"/> Current Selection :

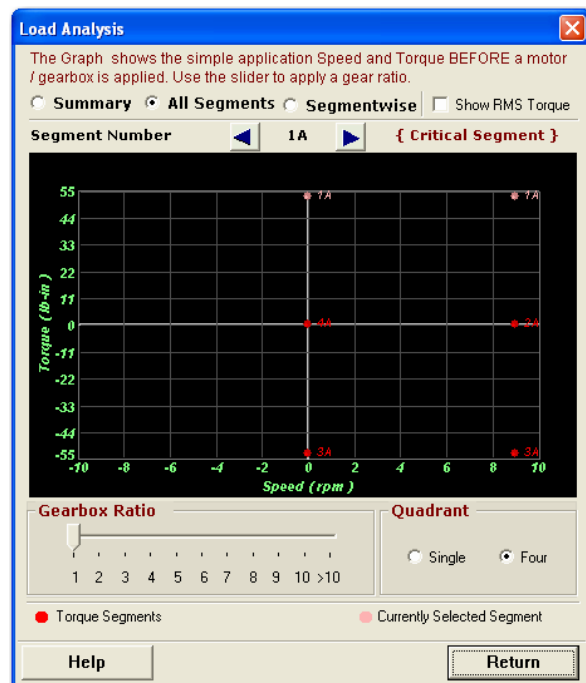
Select Manual to choose your Components.  
Select Automatic to have Motion Analyzer select for you.

34. Here you can see the other choices that are compatible with our 460Vac Kinetix 6000 drive family. We will not be changing our selection. Press **OK** to continue.

- **1326AB** motors are chosen for medium inertia applications.
- **MPC** motors are not available.
- **MPF** motors are the food grade version of the MPL motor.
- **MPL** motor(s) are the most commonly used motor. They are great for low inertia applications.
- **MPS** motors are the Stainless Steel wash down rated version of the MPL motor.



35. A helpful tool provided in Motion Analyzer is the **View Load Graph** feature. If you are having trouble finding a valid motor and drive combination with the automatic search tool, it may be that your solution requires too much torque or speed than the selected motors can produce. Click on this button to see our requirements.



36. It seems that our required speed (RPM) is very low, considering that these motors can go up to 5000-6000 RPM. The torque does seem a little high, so we probably need a gearbox. Try using the **Gearbox Ratio** slider to change your motor speed and torque. We'll see if we can find a solution without a gearbox first. Press **Return** to close the tool.

37. With the selection mode set to **Automatic** for the motor and the drive, press the **Search** button.

Please choose the mode of selection :

	Manual	Automatic		
Motor	<input type="radio"/>	<input checked="" type="radio"/>	Select	Current Selection :
Drive	<input type="radio"/>	<input checked="" type="radio"/>	Select	Current Selection :

Select Manual to choose your Components.  
Select Automatic to have Motion Analyzer select for you.

View Load Graph Search

38. **Wait** while the software searches for all valid solutions (based on your preferences).

Search In Progress

Motion Analyzer is searching the suitable solution for this axis. Click 'Abort' to abort the search.

Abort

39. Verify that you are only displaying the valid solutions. Make sure that only **View Categories 1 and 2** are checked, as follows:

View Categories  Pass 1  Caution 2  Near Fail 3  Far Fail 4 Solution View Setup View Solution

**Solution List**

Depending on the preferences selected for the 'max. Inertia ratio', or 'Show all Inertia' or 'Show the solutions within the max. inertia ratio', it is possible to be presented with solutions which seem unreasonable. However if the user is just doing a first pass analysis it is reasonable to use the 'Show the solutions within the max. inertia ratio' and expect a large quantity of failing results.

This screen summarises the results of an automatic search with colour codes to indicate status:-

Colour	State	Status	Meaning
1	1	Pass	All parameters passed
2	2	Caution	One or more parameters exceeded the recommended limit but the solution is viable provided all customer data is accurate
3	3	Near Fail	One or more parameters exceeded 100%. The solution is not viable as entered but may respond to optimisation (e.g. changing gear ratio, reducing load requirement etc.)
4	4	Far Fail	One or more parameters exceeded 500%. Optimisation is unlikely to bring the solution into viability but should be considered a 'last resort'.

40. Obviously, our suspicions were correct; we need a gearbox. Our **Solution List** is completely empty.

The selected axis has no solutions available.

List Categories by : Peak Speed View Utilizations as :  Text  Graphical

Sol State	Motor	Drive	M+D Cost	General Ra...	Performance Rating	Peak Speed ▲	Winding Temp	Peak Torque	Bus U



41. Another way to see what the problem is would be to check the box for **View Categories 4**, the “**Far Fail**” solutions.



Motion Analyzer displays the list of (failed) motor and drive combinations. The color codes indicate whether a parameter exceeds your “safety margin” setting or exceeds the capacity of the product (like these). The motors displayed are actually quite large; why?

The selected axis has 29 solutions. Select the desired solution from the list below and click View Solution to view its performance.

List Categories by : Winding Temp View Utilizations as : Text Graphical

Sol State	Motor	Drive	M+D Cost	General Rating	Performance Rating	Peak Speed	Winding Temp	Peak Torq
4	MPL-B960C	2098-DSD-HV220	100%			19	-31%	
4	MPL-B980E	2098-DSD-HV150	97%					
4	MPL-B980C	2098-DSD-HV150	97%					
4	MPL-B980B	2098-DSD-HV150	97%					
4	MPL-B960B	2098-DSD-HV150	92%			19	-31%	
4	MPL-B880C	2098-DSD-HV220	90%			19	-31%	
4	MPL-B860D	2098-DSD-HV220	85%			09	-31%	
4	MPL-B880D	2098-DSD-HV150	85%			09	-31%	
4	MPL-B680F	2098-DSD-HV150	65%			09	-31%	
4	MPL-B680D	2098-DSD-HV150	65%			09	-31%	

Red = "bad."

42. Use the **scroll bar** at the bottom to scroll over to the right. You can see that our high load **inertia** is the problem. The load is several *hundred* to several *thousand* times the motor inertia and we want to stay below 10:1. This 24" tool changer weighing 100 lbs is quite large, compared to the motor. We could really use a gearbox.

The selected axis has 29 solutions. Select the desired solution from the list below and click View Solution to view its performance.

List Categories by : Winding Temp View Utilizations as : Text Graphical

Peak Speed	Winding Temp	Peak Torque	Inertia Ratio	Bus Utilization	Average Current	Line Voltage	Slot...	Peak Current
19	-31%	3%	772%	1%	2%	AC3ph, 460 -10%/+10%	1	3%
09	-31%	3%	595%	0%	5%	AC3ph, 460 -10%/+10%	1	8%
19	-31%	3%	595%	1%	3%	AC3ph, 460 -10%/+10%	1	5%
19	-31%	2%	595%	1%	1%	AC3ph, 460 -10%/+10%	1	2%
19	-31%	3%	772%	1%	2%	AC3ph, 460 -10%/+10%	1	3%
19	-31%	3%	941%	1%	2%	AC3ph, 460 -10%/+10%	1	3%
09	-31%	4%	1247%	1%	2%	AC3ph, 460 -10%/+10%	1	4%
09	-31%	5%	941%	0%	4%	AC3ph, 460 -10%/+10%	1	6%
09	-31%	7%	2720%	1%	5%	AC3ph, 460 -10%/+10%	1	8%
09	-31%	4%	2720%	1%	3%	AC3ph, 460 -10%/+10%	1	5%

43. Be sure to **turn off** View Category 4 again.



First, you will only want to look at solutions with a Solution State of “1” because that indicates no criteria failed. Then you will most likely want to pick a solution that has the best cost or inertia ratio. When you consider the inertia ratio, you ideally would like to minimize it but that is always based on how much bandwidth you really need in the application. If it is a point to point move where some overshoot can happen, you could possibly go 10:1 or less and probably be ok. If it is a high bandwidth requirement such as something that does contouring, etc., you try to match it lower, say 3:1 or less. Ideally, you try to match the motor rotor inertia to the load so that they act in unison.

If you look at the drive, you will want to make sure the peak currents/torques are below 80% since any type of loss or friction that is not accounted for may mean the difference from doing an acceleration and deceleration. Motion Analyzer is only as good as what you enter into it. If you look at the motor, you will want to make sure Motor Winding Temperature less than 60% to make up for losses or friction that was not accounted for.

Bus utilization of the drive is next important because if it is exceeded, then there isn't enough DC Bus to spin the motor at the required V/1000rpm that the application needs. Peak Velocity in the motor section tells you what the motor can and can't do based on the input voltage. If the bus utilization is too high, then the motor can not make that move. Many times you need to increase the input voltage, if you can or change to a different motor winding or in the long run, change the cycle profile and/or work with the mechanics.

You can also tell a lot from the speed torque curve. If you are seeing a lot of torque required but only at very low speeds, some kind of reduction may help to improve that situation. Generally, it moves the points down and to the right because the motor generates less torque but requires much higher speed.

For motors that have a low rpm and high RMS torque, you will want to consider a gearbox.

44. Return to the **Selection** tab.



The *Allen-Bradley Integrated Gearmotor* (MPG) would be a great solution for this type of application. It is powerful, compact and has the type of reduction that we need (91:1). Not only that, it can support this tool changer directly, with no additional mechanical components besides a bracket to fasten it to the machine! The problem is that *the designer has already designed the system* and just needs a motor with a gearbox.

45. Select the **Motor with Gearbox** option and be sure that the **SP+** Series is selected. Press the **Search** button again.

The screenshot shows the 'Selection' tab of the software. Under 'Motor Type', 'Motor with Gearbox' is selected. In the 'Gear Parameters' section, 'Manufacturer' is 'Alpha +', 'Configuration' is 'ALL', and 'Series' is 'SP+'. In the 'Motor Parameters' section, 'Max. Inertia Ratio' is '10', and 'Show the Solutions within the Max. Inertia Ratio' is selected. Below this, there are radio buttons for 'Full' and 'User Marked' under 'Database Search Options'. A table allows selecting 'Manual' or 'Automatic' modes for 'Motor', 'Drive', and 'Gearbox'. The 'Motor' row shows 'Current Selection: MPL-B220T', 'Drive' shows '2098-DSD-HV030', and 'Gearbox' shows 'SP060-MF2-100-021'. At the bottom right, the 'Search' button is circled.

This search takes a little more time, while the software optimizes the selection of gear reduction.

46. Once again, a list of solutions is provided. The list can be sorted in a variety of ways, based on your needs. There is still a lot of red, so let's sort our list by cost! Click on the **M+D Cost** column.

The selected axis has 41 solutions. Select the desired solution from the list below and click View Solution to view its performance.

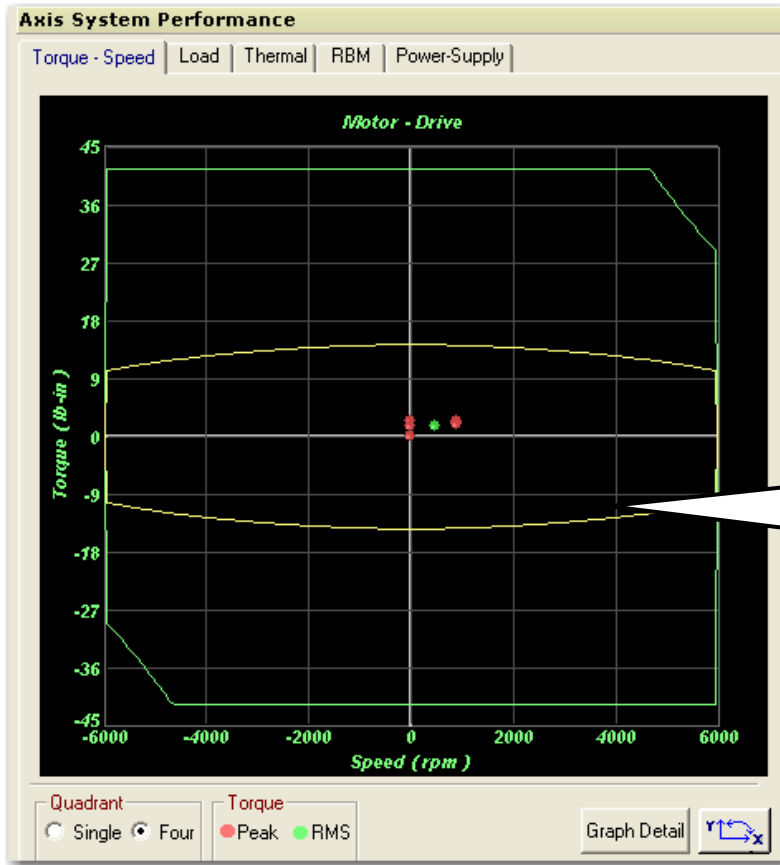
List Categories by : General Rating

View Utilizations as : Text Graphical

Sol State	Motor	Drive	M+D Cost	General Rating	Performance Rating	Peak Speed	Winding Temp	Peak Torq
1	MPL-B430P	2098-DSD-HV030	100%			18%	-29%	
1	MPL-B430P	2098-DSD-HV030	100%			13%	-29%	
1	MPL-B430P	2098-DSD-HV030	100%			9%	-30%	
1	MPL-B430P	2098-DSD-HV030	100%			7%	-30%	
1	MPL-B430P	2098-DSD-HV030	100%			6%	-30%	
1	MPL-B430P	2098-DSD-HV030	100%			5%	-30%	
2	MPL-B430P	2098-DSD-HV030	100%			4%	-30%	
1	MPL-B420P	2098-DSD-HV030	98%			18%	-30%	
1	MPL-B420P	2098-DSD-HV030	98%			13%	-30%	

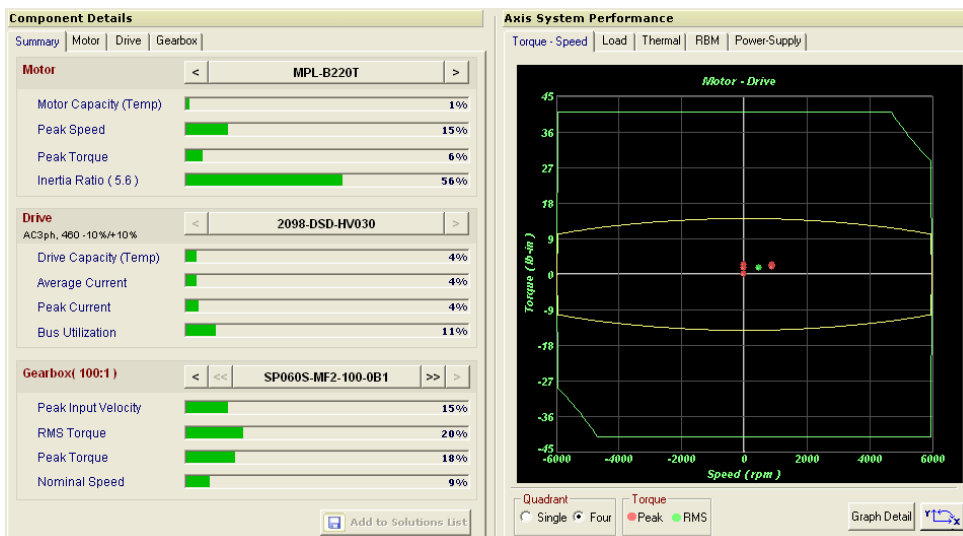


50. Next, look at the **Torque-Speed** curve. Here we see that both the Peak and RMS Torque values are within the *continuous* portion (the yellow lines) of the Torque-Speed curve. The continuous portion means that the motor and drive can safely operate there indefinitely and will not overheat. Occasionally, the torque values can spike into the Peak region, typically for accelerating the load, but this adds to overheating the motor or drive. The software models the amount of time the motor and drive are in the peak zone when calculating the “Capacity” values.

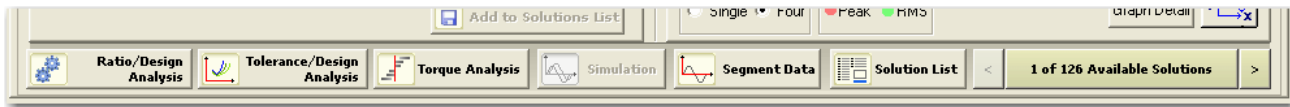


The 4-quadrant Torque-Speed curve shows positive and negative motor speeds as well as positive and negative (regenerative) torques.

A 100:1 gearbox now allows us to use one of the smallest motors and drives available. Why? Because the high inertia of the tool changer is reduced by the *square* of the gear ratio ( $100^2 = 10,000:1$ ), while the motor speed requirement only increases 1:1 with the gear ratio. Ah, physics!



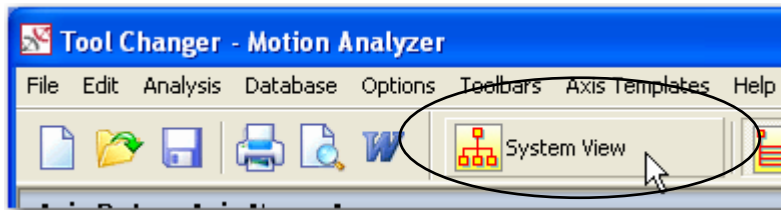
51. There are many **additional analysis tools** included with Motion Analyzer, shown at the bottom of the screen. Each one helps optimize the motor and drive selection and possibly remove costs from the system.



- **Ratio/Design Analysis** gives great insight on what the best gear ratio (or belt reduction ratio) may be, based on the motor and drive parameters.
- **Tolerance/Design Analysis** offers the ability to examine the crucial system parameters as one system variable changes, such as line speed or product weight.
- **Torque Analysis** and **Segment Data** help to investigate what aspect of the system require the most torque during a duty cycle. It is often surprising where the losses or requirements are originating.

Look for additional (advanced) labs available on these topics.

52. Return to the **System View**.

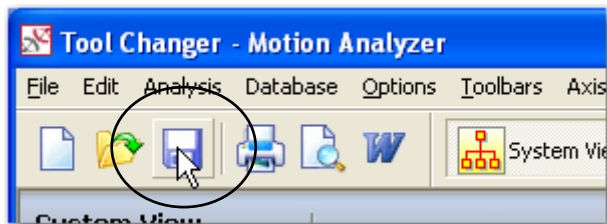


53. Observe all of the **icons** that represent our selected components. Our motor, drive and gearbox selection are even specified.



Drive, motor, gearbox, rotary load and cycle profile (shown above).

54. **Save your work** at this point. Answer **Yes** to the prompt about the shunt and select a place to save your file.

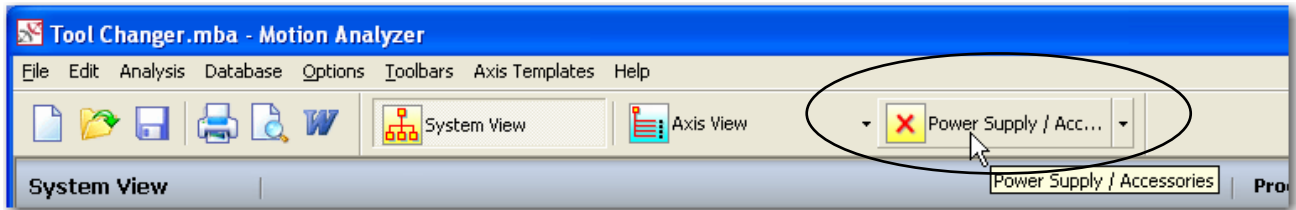


## Analyze the System Shunt Requirements

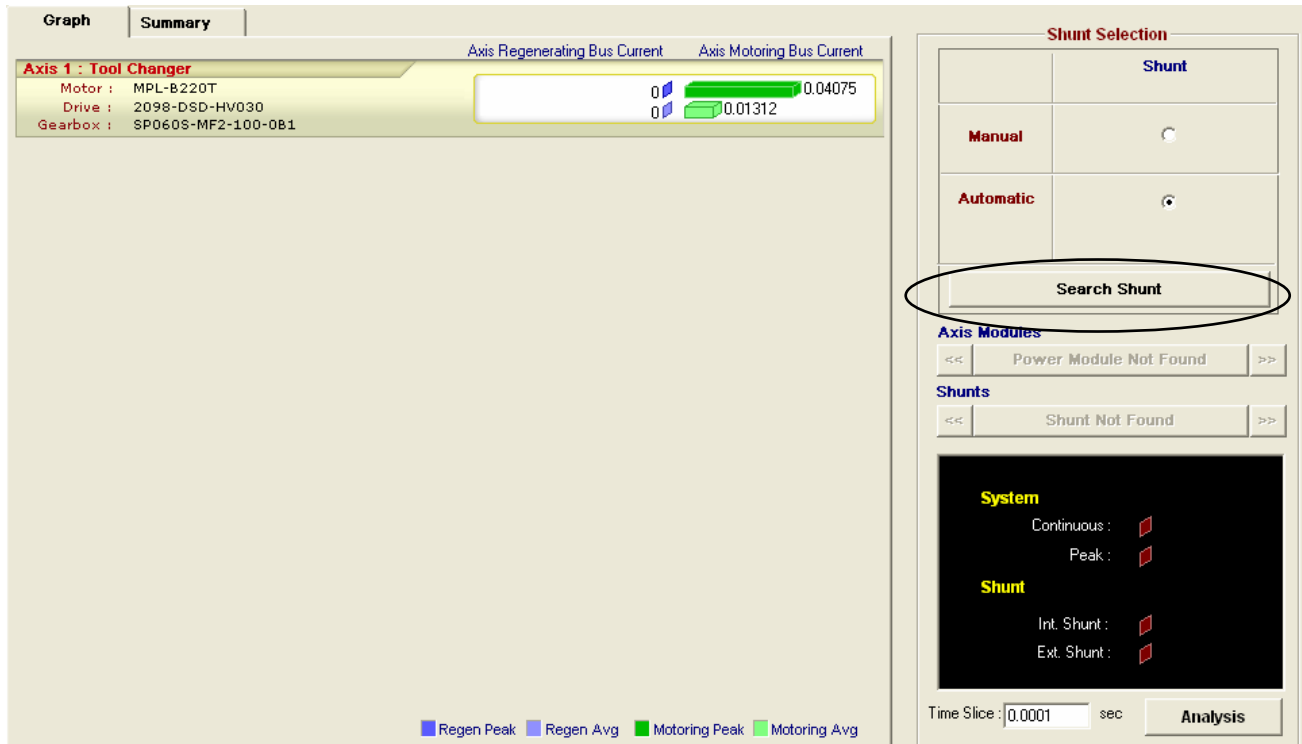
You may have noticed the prompt that appeared when you saved your work. It mentions a system shunt.

Most servo drives contain a shunt resistor that helps to prevent the internal power bus from an overload. This is typically a concern when stopping the axis; especially when stopping a large inertia wheel, like our tool changer. Our Ultra 3000 drive includes an internal shunt resistor, but let's see if it sufficient on its own or if we need additional capacity.

55. To determine if your system requires additional shunting components, click on the **Power Supply / Accessories** button at the top of the screen.



56. Press the **Search Shunt** button to automatically size and select any required components.



57. The software shows that we do *not* require any additional shunting components. The internal shunt resistor is sufficient in this application.

The screenshot displays the 'Summary' tab of the Motion Analyzer software. On the left, the 'Axis 1 : Tool Changer' parameters are listed: Motor: MPL-B220T, Drive: 2098-DSD-HV030, and Gearbox: SP060S-MF2-100-0B1. Two bar graphs show 'Axis Regenerating Bus Current' (0.04075) and 'Axis Motoring Bus Current' (0.01312). On the right, the 'Shunt Selection' panel includes a 'Shunt' table with 'Manual' and 'Automatic' radio buttons, a 'Search Shunt' field, and 'Axis Modules' set to '2098-DSD-HV030'. The 'Shunts' section shows 'Internal Shunt Present' and 'Ext. Shunt : Not Selected'. Below this, a 'System' analysis window shows 'Continuous : 0.1874%' and 'Peak : 0.2911%'. A callout box points to the 'Internal Shunt Present' status with the text 'No additional shunting is required.'

If your system requires external shunting, be sure to keep the continuous usage percentage below 20%. These types of chopper/resistor sets are typically rated for a 20% duty cycle. If you are an inverter drive user, you already know this.

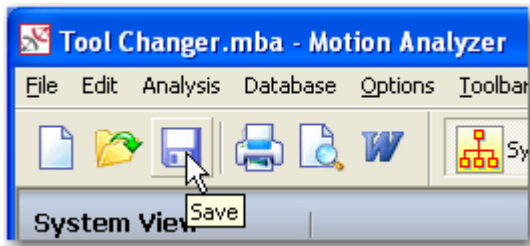
This is a close-up of the 'System' analysis window from the screenshot above. It shows 'Continuous : 0.1874%' and 'Peak : 0.2911%'. Under the 'Shunt' section, it shows 'Internal Shunt : 0%' and 'Ext. Shunt : Not Selected'. A callout box points to the continuous usage percentage with the text 'If used, keep this rating below 20%.'

58. Return to the **System View** as before.

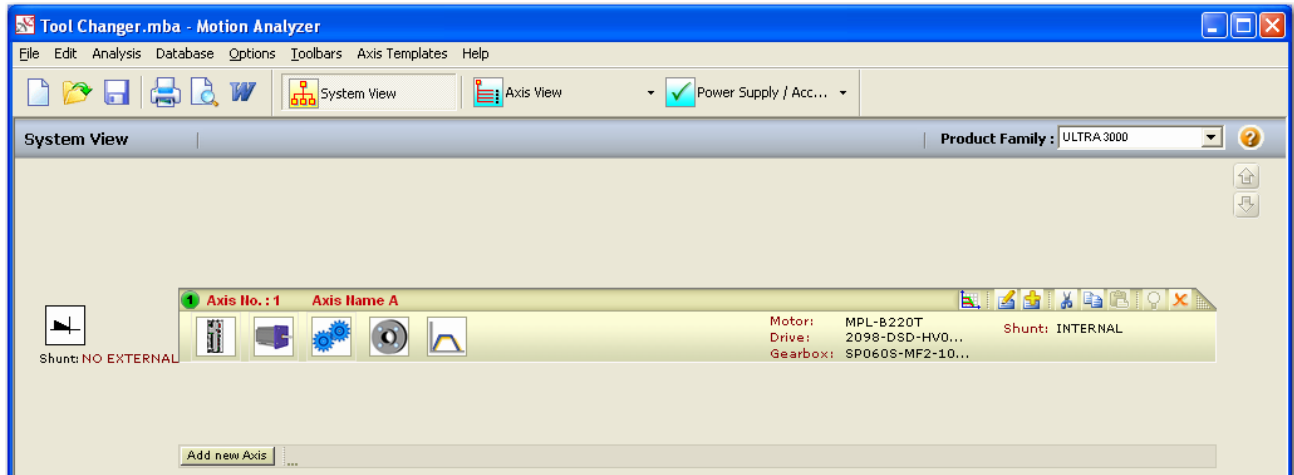
The screenshot shows the top of the Motion Analyzer application window. The title bar reads 'Tool Changer.mba - Motion Analyzer'. The menu bar includes 'File', 'Edit', 'Analysis', 'Database', 'Options', 'Toolbars', 'Axis Templates', and 'Help'. Below the menu bar is a toolbar with various icons. The 'System View' button, which has a tree icon, is highlighted by a mouse cursor.



59. **Save** your work.



Your system is now complete! You can see the motor, drive and gearbox part numbers.



**This concludes the Rotary Axis Lab.**