

SHERLINE PRODUCTS

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SHERLINE CNC ROTARY INDEXER

P/N 8700

NOTE: When used on a Sherline CNC mill or a standard Model 5400 or 2000 mill, a tilting angle table or 1/2" spacer plate may be required in some setups to avoid interference with the Y-axis handwheel or stepper motor mount.

INTRODUCTION

By Joe Martin

Bryan Mumford and I are very proud of this product. It has taken Sherline twice the investment in both time and money compared to what we originally planned. We have taken a very expensive product that has only been available to very successful professional businesses and produced a self-contained unit that not only has the features of the expensive units, it is also simpler to use and very affordable. In fact, it is so inexpensive, home hobbyists can now afford to own and use this equipment. It should also be noted that we didn't copy anyone to accomplish this feat. My only disappointment was that I was unable to find a way to adapt our existing rotary tables to a CNC unit. It just couldn't be done in a cost-effective manner because of the mechanical parts that couldn't be interchanged due to the way the rotary table is manufactured.

Bryan Mumford, who designed the electronics and did the programming, has written the basic instructions for the computer. Even though the computer is small, it is a very complex device that both computes and drives the stepper motor in microsteps. Like all electronic devices, the easier it is to operate, the harder the device is to design and program. I believe Bryan's instructions are easy to read and shouldn't give you any problems, but if they do, please notify us at Sherline, and we will attempt to improve them. We want our instructions to be the best in the business. The most important rule is to always work safely and accurately.

POSITIONING ACCURACY

The first thing to understand about the rotary table is the accuracy that can be obtained in real terms. The stepper motor takes 400 steps to make exactly one revolution. This motor drives the worm, which needs to make 72 revolutions to make the rotary table turn exactly one revolution. This means that it takes 28,800 steps (400 x 72) to drive the rotary table one complete revolution. Take this number and divide by the number of degrees in a circle (360°) and we end up with 80 steps for each degree or 0.0125° (or

0.75 minutes) for each step. The built-in computer will calculate to the closest position. This means the final position will be within $\pm \frac{1}{2}$ step maximum. This turns out to be a very small amount, because the sine of this angle is only 0.0001091. This will amount to 0.109" (2.77mm) rise in 1000" (83'- 4" or 25.4 m) when compared to a flat plane. This is just .00022" (.0055mm) at the edge of the table.

MECHANICAL ACCURACY

The gear that turns electronic signals into a real movement has been hobbled directly into the table, which means the teeth have been generated on a machine that cuts the teeth with a cutter similar to a worm as the part is turning. This eliminates any error associated with cutting each tooth individually. As anyone associated with the machine trades realizes, "nothing is perfect". This is also the case for this product; however, I seriously doubt if anyone buying it could measure the mechanical indexing error of the worm and gear. The electronic system has no error in its calculations, but it does round off as previously explained.

THE IMPORTANCE OF READING THE INSTRUCTIONS

It is impossible to make a product this complex "idiot proof". The best rule I've ever come up with when dealing with any type of CNC equipment is this: "You have to know what the unit will do after you push the button BEFORE you push the button." This can only be accomplished by reading the instructions and "playing with the rotary table" at the same time until you thoroughly understand how the features of this unit work. Don't mount this unit on a mill that has a cutter in the spindle until you truly understand how to operate it.

PRECAUTIONS WHEN TURNING ON THE UNIT

- As with any piece of electronic equipment, make sure the power is off before plugging the stepper motor connecting cord into the control unit.
- If a part has been aligned on the table and the power is switched off, the part should be realigned after turning the unit back on before continuing. Electrical "spikes" can cause the motor to move a few steps when turning it on. The power can be left on continuously without damage.

OPERATION INSTRUCTIONS

by Bryan Mumford

The Sherline Rotary Table Controller is a self-contained microprocessor-based controller that will automate the motion of the Sherline rotary table. Though you can still crank the table by hand when in the jog mode or when the controller is turned off, the controller is designed to crank it for you in precise, measured steps.

MOVING THE TABLE

There are two primary ways to move the table:

1) Using the **DIVISION MODE** you can enter a number of equal divisions in which to divide one rotation of the table. For example, if you enter “4”, the table will move in 90 degree steps ($360 / 4 = 90$). A typical application of this mode would be gear cutting.

2) Using the **DEGREES MODE** you can specify the exact number of degrees to move the table. For example, if you enter “132.130”, the table will move 132.130 degrees.

In addition, you can enter a series of programmed steps. For example, you can have the table move 90 degrees, then 132 degrees, then reverse rotation 20 degrees, etc. You can enter up to 40 steps in each of two separate programs. You can also specify the speed of rotation (feed rate) for each step, and whether the table is to pause and wait after a step is taken or move continuously.

Finally, you can use the **JOG MODE** to move the table clockwise or counterclockwise with the keypad on the controller.

GENERAL SPECIFICATIONS

- The resolution of positioning is +/- .006 degrees.
- The speed of rotation can be set from very slow rate of one degree per second to a maximum of 50 degrees per second. Note that the higher speeds do not have much power and will only be used for positioning the table quickly, not for cutting operations.
- The controller uses “ramping” to accelerate and decelerate during each step. You can enter the minimum and maximum speeds used to suit your work. (The amount of ramping becomes more noticeable when the slow feed is set below 10 in the settings mode.)
- The controller allows a programmable amount of backlash compensation.

USING THE CONTROLLER

The controller must be plugged into its AC adapter power supply. The power jack is located on the end of the unit. It is turned on with the toggle switch located next to the power jack. With the power turned off, the motor cable must be plugged into the 5-pin DIN connector next to the power switch.

The basic operation of the controller is to press the [MODE] key to advance from one mode of operation to the next. This will cycle through the various modes of operation. When the mode you wish to use is displayed, press the [ENTER] key to start that mode and enter the parameters

of operation. The four modes are:

- Division
- Degrees
- Program
- Settings

THE DIVISION MODE

The Division Mode allows you to specify a fixed number of steps per rotation of the rotary table. For example, you might specify “four” divisions. Then, each time you tell the table to advance, it will rotate one fourth of 360 degrees, or 90 degrees.

When you first turn on the controller, it will say “Sherline Rotary Table”. Press the [MODE] key once to advance to the first mode. The LCD screen will say:

Division Mode

Press [Enter]

To use the Division Mode, press the [ENTER] key. The LCD screen will then say:

Divisions: 000

Enter a number

You should now enter the number of divisions in which you wish to divide the rotation. When you press a number key, that number will appear on the LCD screen where the cursor is blinking. To move the cursor left, press the [PRV] (Previous) key. To move the cursor right, press the [NXT] (Next) key or type any digit. You can enter any value between zero and 999 divisions. (Zero is a special case. It will cause the table to run continuously until you stop it. See the section below labeled “Continuous Motion” for an explanation of this action.)



FIGURE 1—The controller keypad

When the number of divisions you want is displayed, press [ENTER]. For example, suppose you typed “030” for the number of divisions. After you hit the [ENTER] key, the LCD screen will say:

*Division # 1
Press Nxt or Prv*

This means that the table is at position one (of 30), and it is waiting for you to press the [NXT] or [PRV] keys. If you press [NXT], the table will advance 12 degrees clockwise, and the LCD screen will say:

*Division # 2
Press Nxt or Prv*

If you had pressed the [PRV] key, the table would move 12 degrees counterclockwise, and the LCD screen would say:

*Division # 30
Press Nxt or Prv*

It says “Division # 30” because it went backwards one position, from one to 30.

There is a special function available in the Division Mode. After you have set the controller up to step with the [NXT] and [PRV] keys, you can press the [MINUS] key. This will cause the table to take one division step every second, with a one-second delay between steps. It will continue making the programmed movement with one second delay between steps until you stop it with the [STOP] (JOG) key. (If the [STOP] key is hit between steps while the table is not moving, it must be held down longer than one second to stop the movement.)

PANIC STOP—Any time the table is moving, you can stop it immediately by hitting the [STOP] (Jog) key. This will stop all motion and put you into the JOG mode. You to lose your place in the program you were running and will have to start over.

To exit from the Division Mode, press the [MODE] key.

THE “DEGREES” MODE

The Degrees Mode allows you to specify the exact number of degrees the table will rotate every time you tell it to advance. Keep in mind that the resolution of the table is .0125 degrees. This means, for example, that it cannot move to a position like “0.010” degrees which is not an even multiple of “.0125”. However, the table keeps track of exactly where it’s supposed to be and where it is actually able to go, and always gets as close to the correct location as is possible (within .006 degrees).

When the LCD screen says “Division Mode” you can press the [MODE] key once to advance to the Degrees Mode. The LCD screen will say:

*Degrees Mode
Press Enter*

To use the Degrees Mode, press the [ENTER] key. The LCD screen will then say:

*Degrees: 000.000
Enter a number*

You can now enter the number of degrees you wish to

travel at each step. When you press a number key, that number will appear on the LCD screen where the cursor is blinking. To move the cursor left, press the [PRV] (Previous) key. To move the cursor right, press the [NXT] (Next) key or type any digit.

You can also specify whether the table is to move clockwise or counterclockwise when you enter the number of degrees to move. To enter a counterclockwise value, press the [MINUS] key. This will add a minus sign before the degree amount, indicating reverse travel. If the degree size is negative, the [NXT] key will move the table counterclockwise and [PRV] will move clockwise. To make a negative value positive again, press the [MINUS] key again.

(Note that it is also possible to change the default direction of travel from clockwise to counterclockwise. See the SETTINGS mode for details.)

You can also tell the controller to step zero degrees. This is a special case. It will cause the table to run continuously until you stop it with the [STOP] key. See the section below labeled “Continuous Motion” for an explanation of this action.

When the number you want is displayed, press [ENTER]. For example, suppose you typed “020.000” for the number of degrees. After you hit [ENTER], the LCD screen will say:

*020.000 000.000
Press Nxt or Prv*

The first number is the step size you selected (20.000 degrees). The second number is the current position (000.000 degrees). The controller is waiting for you to press the [NXT] or [PRV] keys. If you press [NXT], the table will advance 20 degrees clockwise, and the LCD screen will say:

*020.000 020.000
Press Nxt or Prv*

The current position is now shown to be 20 degrees. If you press [NXT] again, the screen will show:

*020.000 040.000
Press Nxt or Prv*

The current position is now shown to be 040.000 degrees.

If you had pressed the [PRV] key the first time, the table would move 20 degrees counterclockwise, and the LCD screen would say:

*020.000 340.000
Press Nxt or Prv*

The current step is shown to be 20.000 degrees and the current position is 340 degrees (360 degrees minus 20 degrees).

PANIC STOP—Any time the table is moving, you can stop it immediately by hitting the [STOP] (Jog) key. This will stop all motion and put you into the JOG mode. You to lose your place in the program you were running and will have to start over.

To exit from the Degrees Mode, press the [MODE] key.

THE "PROGRAM" MODE

The Program Mode allows you to prepare a list of many steps to take one after another. For each step you will enter four parameters:

- 1) The number of degrees to move,
- 2) The direction of travel (clockwise or counterclockwise),
- 3) The feed rate for that move, and
- 4) Whether or not the table should wait for you to hit the [NXT] key after each step is taken.

The program you enter will be remembered indefinitely (unless you change it), even if you turn the controller off. There is room for two separate programs of 40 steps each.

Before you enter your program steps, you'll want to plan them carefully to be sure they're correct before typing them all in. Write them down on paper and check for errors.

The Program Mode comes after the Degrees Mode. Press the [MODE] key until the screen says:

Program Mode
Press Enter

Then press the [ENTER] key. The screen will say:

Which program?
Press 1 or 2...

You can now select which program you will use; the first one, or the second one. Type the digit "one" or "two" and the screen will say something similar to:

Program 1
Run=PRV Edit=NXT

This indicates which program you've selected, and that you should press the PRV key to run the program that was stored previously, or press the NXT key to enter a new ("next") program.

ENTERING A NEW PROGRAM

If you press the [NXT] key, the LCD screen will show you the degree setting for the first program step and allow you to change it. For example, the screen might show something similar to this:

Step 1:1
Degrees: 090.000

The "1:1" means you're working on program one, step number one. The first step in this example will move the table 90 degrees clockwise. To change this amount, type the number keys. You can press [NXT] to move the cursor to the right, or [PRV] to move the cursor to the left.

You can indicate whether you want the table to move clockwise or counterclockwise. To enter a counterclockwise direction, press the [MINUS] key. This will place a minus sign before the degree amount, indicating reverse travel. If you press the [MINUS] key again, the minus sign will be removed and the direction will be clockwise.

(Note that it is also possible to change the default direction of travel from clockwise to counterclockwise. See the SETTINGS mode for details.)

When the screen shows the step size you wish, press the [ENTER] key to enter (and store) your selection.

The screen will then say something similar to this:

Step 1:1
Feed rate: 15

This means that the feed rate for this programmed step is 15 degrees per second. The number you enter will be the fastest rate the table will reach during a move. The SLOW rate (the rate it starts at each time) depends on what you entered for SLOW in the Settings Mode. You can change the feed rate to anything between 1 and 50 degrees per second.

When the screen shows the feed rate you wish to use, press [ENTER] again. The LCD screen will then show something similar to:

Step 1:1
Pause

You can tell the controller to pause after each step or continue to the next step. If you tell it to pause, you must hit the [NXT] key during program execution before it will advance. To set the current program step to pause, press the "7" key (marked "slow"). To set the current program step to NOT pause, press the "9" key (marked "fast").

After setting the PAUSE parameter how you want it, hit the [ENTER] key. The LCD screen will then show something similar to:

Step 1:2
Degrees: 000.000

This indicates that you're ready to program the step size for step number 2 in the first program. You can now define the step size, feed rate, and pause status just like you did for the first step.

When you've entered all of the program steps you wish, terminate the program by entering a step size of "000.000". This tells the controller to stop asking for new input and prepares to run the program you've just entered.

INSERT AND DELETE

When entering a program you may make a mistake, or you may wish to modify a program after it has been entered. You can INSERT and DELETE program steps to correct or modify an existing program. To access the INSERT and DELETE functions, press the [MODE] key while the controller is waiting for you to enter the number of degrees for any program step. (You can't use INSERT or DELETE after entering the degree size.) The LCD screen will then say something similar to:

Step 1:5
Insert?

You can now insert a new step at this point in the program by hitting the [ENTER] key. The LCD screen will say something similar to:

Step 1:5
Wait...

After a few seconds the word "Wait..." will go away and

you will be able to enter a step size for the new, inserted position.

If you do not INSERT a program step but rather press the MODE key a second time, the controller will say:

*Step 1:5
Delete?*

You can now delete the current program step by hitting the [ENTER] key. The LCD screen will say something similar to:

*Step 1:5
Wait...*

After a few seconds the word “Wait...” will go away and the previous settings for that program step will have been removed and replaced by the settings for the next program step.

If you do not INSERT or DELETE a program step but rather press the [MODE] key a third time, the controller will say:

*Step 1:5
Exit?*

You can now terminate the programming session entirely by pressing the ENTER key. Or, if you press the MODE key a fourth time, the controller will return to the editing mode.

RUNNING A PROGRAM

If you press the [PRV] key when you first enter the Program Mode, or after you have entered zero for a program step size, you’ll be able to run your program. The LCD screen will show you the degree setting for the first program step. For example, the screen might show something similar to this:

*Step 1:1 090.000
Press [NXT]*

It’s telling you that it’s ready to take step number one in program one, which is 90.000 degrees, and the table will move by this amount when you press the [NXT] key. While the table is in motion, the screen will say:

Moving...

If the step was set to pause, it will then wait for you to hit the [NXT] key. When the step is complete, the screen will show you the setting for the next programmed step which will be taken immediately.

You can terminate execution at any time by pressing the [MODE] key, which will allow you to go back and enter a new program or start running the same one over again.

You can press the [STOP] key at any time to abort table motion and enter the Jog Mode.

After all of the steps in the program are completed, the program will start over and wait for you to hit the [NXT] key.

NOTE: If the controller seems to refuse to run a program, it is probably because the first step in the program has been defined as “000.000” degrees. If this happens, try to EDIT the program and see if the first step is set to zero degrees.

THE SETTINGS MODE

The next mode after the Program Mode is the Settings Mode. This allows you to enter some parameters of operation for the table. These settings are remembered even when you turn the controller off.

SLOW SETTING

When the screen says:

*Settings Mode
Press Enter*

Press the [ENTER] key. The screen will then say something similar to:

*Slow: 15
Enter a number*

The number after the word SLOW is the minimum feed rate of the table. This is the speed with which the table starts each movement. The units are degrees per second, and may range from 1 (very slow) to 20 (medium). Whenever the table moves, it starts at the SLOW feed rate and ramps up to the FAST feed rate. It also ramps down to the SLOW rate before stopping.

When the screen shows the value you wish to use for SLOW, press the [ENTER] key. The value will be stored and remembered for all future operations.

FAST SETTING

The screen will then say something similar to:

*Fast: 40
Enter a number*

The number after the word FAST is the maximum feed rate of the table. This is the maximum speed the table reaches in each movement. The units are degrees per second, and may range from 1 (very slow) to 50 (very fast). Whenever the table moves, it starts at the SLOW feed rate and ramps up to the FAST setting. If you set the FAST rate the same as the SLOW rate, the rate of motion will be constant during the move. The table does not have much power at the fastest settings, so very fast settings should only be used for positioning, not for cutting operations. Experience will teach you what speeds are appropriate for your own work.

When the screen shows the value you wish to use for FAST, press the [ENTER] key. The value will be stored and remembered for all future operations in the DEGREES and DIVISION modes.

DIRECTION SETTING

The screen will then say something similar to:

*Direction: 3
Press 1 or 3*

This parameter allows you to enter the default direction of travel. Whenever these instructions say “clockwise” or “counterclockwise”, they assume the default direction is set to be clockwise. If you need the table’s motion to be counterclockwise most of the time, this can be arranged.

If you type the “3” key (marked with a right arrow) the default direction will be set to clockwise. If you type the

number “1” key (marked with a left arrow) the default direction will be set as counterclockwise.

SETTING THE ELECTRONIC BACKLASH COMPENSATION

The physical backlash in the worm gear can be minimized with proper adjustment (See “Maintenance”, page 11); however, it cannot be eliminated. The controller supports electronic backlash correction to compensate for whatever actual backlash remains in the worm gear. It works in this way: Every time the table makes a motion in the “reverse” direction, it will overshoot the amount of travel by the backlash amount, and then move “forward” by the same amount. This takes up any backlash in the worm gear. You can set the backlash correction to any amount you like. If you set it to zero, it will not be used. If you set it to a small amount, it can just exactly take up the backlash in your rotary table. If you set it to a relatively large value, you can see the table overshoot and then return to correct position.

The LCD screen will say something similar to:

*Backlash: 010
Enter a number*

The number represents the number of motor steps to overshoot by.* When you have typed the backlash setting you want, press the [ENTER] key to store it. The controller will then go back to the Division Mode.

*NOTE: 8 steps = 1 division line on the handwheel.

You can determine how much backlash to use by trial and error and your own preference. To evaluate the current backlash setting, go to the DIVISION mode. Enter something like 50 divisions. Hit the [PRV] key. The table will move in the reverse direction and overshoot the distance specified by the backlash amount, then change direction and move forward by the backlash amount. If the backlash setting is small, you won’t notice it. If it is large, it will be easy to see.

THE JOG MODE

The Jog Mode allows you to quickly move the table in clockwise and counterclockwise directions with the keypad. To enter the Jog Mode, press the [STOP] (Jog) key.

In Jog Mode the motor is unpowered. This means you can turn the crank by hand for fine positioning. You can also hold down the “1” or “3” keys for rapid, motorized motion. “1” will move the table counterclockwise, “3” will move it clockwise. You can also take very fine, slow steps. [NXT] will move the table clockwise, [PRV] will move it counterclockwise.

When you are finished with the Jog Mode, press the MODE key to go back to the Division Mode.

NOTE: In addition to using it in the Jog Mode, you can also press the [STOP] (Jog) key at any time the table is moving, and it will serve as a PANIC STOP, immediately stopping the table in place. In any mode other than the Jog Mode, if the table is in motion and you want to stop it immediately, simply press the [STOP] (Jog) key. Doing so leaves the table in the JOG mode, and it will need to be reset to your previous mode before continuing.

CONTINUOUS MOTION

You can put the table into continuous motion by entering zero for the number of divisions in the Division Mode, or zero for the number of degrees in the Degrees Mode. During continuous motion, the table will start moving at the SLOW speed setting, ramp up to the FAST speed setting, and keep turning until you stop it with the [STOP] key. When the table goes into Continuous Motion, the LCD screen will say something similar to:

*Hit [JOG] to stop
Feed rate: 40*

The first line serves to remind you how to stop the motion: by hitting the [JOG] key.

The second line shows you what the current setting of the FAST feed rate is. You can now change the speed of rotation with the keypad while the table is turning. If you press the “7” key (labeled “Slow”), the feed rate will decrease. If you press the “9” key (labeled “Fast”), the feed rate will increase. In this way, you can find the speed setting that works best for you. As the speed changes, the new rate is assigned to the FAST speed setting and shown on the LCD screen.

As you decrease the FAST feed rate, if the value goes lower than the current setting for the SLOW feed rate, the SLOW setting will also be reduced to the same value. (You can’t have the SLOW setting be faster than the FAST setting.)

INTERFACE OPTIONS

There are two interface options for the controller. They both use the 8-pin mini-DIN connector at the top end of the controller case. The interface options are:

- Step and direction signals for use with other motor controllers.
- Sense and acknowledge signals for handshaking with other CNC controllers.

STEP AND DIRECTION INPUT

If you have a motor controller that outputs STEP and DIRECTION signals for a fourth axis, you can use the Sherline CNC rotary indexer to receive these signals and move the table. You’ll need a cable to connect the STEP and DIRECTION signals of your other controller to the proper pins of the interface connector on the end of the Sherline controller.

You must put the Sherline controller into a special “Slave Mode” to work with these signals. To do this, hold down the “1” key on the keypad when you first turn on the controller. You should see a message that says:

Slave Mode

In this mode the controller will wait for a low-going STEP command. As soon as it is found, the table will move .0125 degrees clockwise if the DIRECTION input is high. If the DIRECTION input is low, the table will move .0125 degrees counterclockwise. There are 28,800 steps in a full rotation of 360 degrees.

To stop using the slave move, turn the controller off, wait 5 seconds, and turn it on again.

SENSE AND ACKNOWLEDGE INPUT

Some CNC controllers support a SENSE and ACKNOWLEDGE protocol for a fourth axis. In Haas CNC machines, this is implemented with command “M21”. When the M21 command is executed, the Haas controller closes a relay and then waits for the “M-FIN” input line to go high (open circuit) while the remote device is operating. When the remote device has finished, it must short the M-FIN line to ground to acknowledge that the action is complete.

The Sherline Rotary Table Controller supports the M21 protocol. There is a SENSE input line and an ACK output line in the interface connector. The SENSE input is made active by shorting it to ground. It is left inactive by leaving it unconnected to ground, or by pulling it to 5 volts. The ACK output is an “open collector” drive signal. It can be used like a switch closure. When it is active, it will be connected to ground. When inactive, it will be an open circuit. The ACK output will work with signals as high as 30 volts.

The SENSE input works just like the [NXT] key on the controller. In any of the motion modes (Division, Degrees, or Program) where you can move the table by pressing the [NXT] key on the keypad, you can also move the table by shorting the SENSE input to ground. You can use some other CNC controller to make the SENSE input low (for example, the M21 command), or you can make a simple push button switch on a cord to short the SENSE input to ground. This will allow you to step the table with a hand held push-button rather than the keypad of the controller. Some people may wish to mount the push-button on the milling machine, so the CNC motion of the mill can press the button in a programmed operation and cause the rotary table to advance. This is a “poor man’s” 4th axis.

To connect your CNC controller to the Sherline Rotary Table Controller, add a relay to your CNC machine. Connect the relay switch contacts to the Sherline controller SENSE and GROUND lines. When your controller closes the relay, it will trigger the Sherline controller.

Every time a motion is initiated by the [NXT] key or the SENSE input, the ACK output of the Sherline controller will be shorted to ground. As soon as the controller has completed the motion, the ACK output will be opened (will not be shorted to ground).

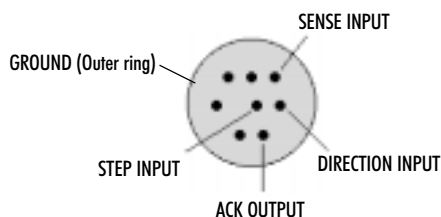


FIGURE 2—Layout of the interface connector

START-UP COMMANDS

There are several utility commands that can be issued by holding down certain keys when the controller is first turned on. For example, to enter the SLAVE MODE (to run the controller with STEP and DIRECTION signals

from another CNC controller, hold down the “1” key when you first turn on the controller.

The four start-up commands are:

- [1] - Enter “Slave” mode
- [7] - Show the revision date of the firmware
- [9] - Erase all program memory locations
- [MODE] - Erase all program memory locations and initialize all settings to factory defaults.

USING THE ROTARY TABLE IN MACHINING

By Joe Martin

The following instructions are included to give you some further insight into the fine points of using a rotary table for machining operations. Sherline Products Inc. makes a wide variety of miniature machine tools, which now includes the CNC rotary table (P/N 8700). For obvious reasons, the descriptions and illustrations use these machines as examples.

MOUNTING THE TABLE TO A FULL-SIZE MILL

Machine tools of this size have very limited work areas, so the tools and accessories manufactured by Sherline are designed to be used in conjunction with one another. If you plan to use this device on full-sized equipment I would suggest mounting the table to a rectangular block of metal.

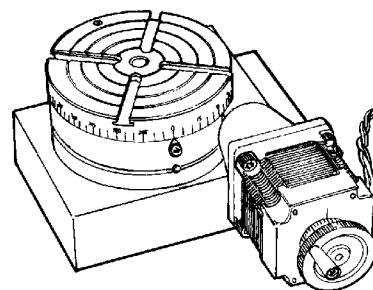


FIGURE 3—Rotary table mounted to a riser block

There are three 10-32 tapped holes on the bottom of the table for this purpose. The holes are 120° apart on a 3.2" (81.28mm) bolt circle. On a Sherline mill, the stepper motor mount overhangs the table, but on a large industrial table, a riser block is needed to keep the

motor mount from interfering with the table surface. When mounted to an aluminum block of sufficient size, the entire assembly can be held in a vise in the horizontal or vertical position, thereby making it easier to use. It can also be mounted on a standard Sherline tilting angle table (P/N 3750). Remember that when operated in an industrial environment, the unit cannot be flooded with coolant.

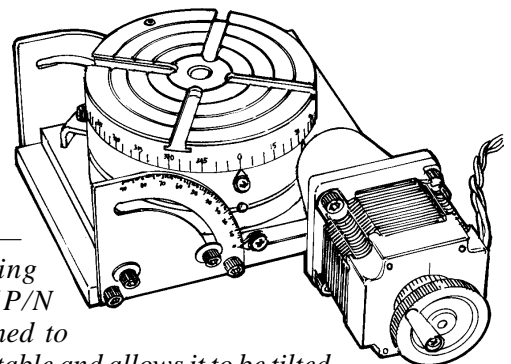


FIGURE 4—Sherline’s tilting angle table (P/N 3750) is designed to hold the rotary table and allows it to be tilted to any angle from 0° to 90°.

Don't let the reasonable price mislead you into believing this is not a precision piece of equipment. During the past thirty years, Sherline has specialized in designing and manufacturing equipment where you, the customer, get the "most bang for the buck".

The following instructions have been written to show what is involved in doing a complex job on a rotary table accurately. In many cases these instructions have nothing to do with how the table is driven. A CNC-driven table can solve the problem of tedious calculations, but it will never solve an error in logic. I believe if you truly understand the job I will describe in detail, average jobs can be accomplished without filling your trash can with mistakes. Remember, there are not many people capable of making the complex machined products used today, and if you can master the vertical mill and the rotary table combination, you will have come a long way at becoming a good machinist. You will find erasers aren't much good and no one has come up with a good "putting on" tool when it comes to metal parts. Complex parts are very difficult to make. When you are making "one-of-a-kind" parts, don't worry about how long it takes. Spend your time planning and checking so you don't have to start over.

When a rotary table is put on a vertical mill, you end up with a machine that is theoretically capable of reproducing itself. Of course, the size of the rotary table has to be considered, and the Sherline table would be too small to accomplish this on a full-size milling machine. But having a rotary table means the capabilities of your mill will be greatly expanded, and only the size of the part and the ingenuity of the operator will govern the complexity of the part. The purpose of these instructions is to give you an insight into properly using this accessory. An inexpensive calculator with trig functions is a must for complex jobs.

Standard milling machine setups usually involve aligning the work with the table and then with the spindle. This is easily accomplished because the table can be accurately moved with the handwheels.

DEALING WITH BACKLASH

When working with a rotary table, the term "backlash" must also be used. Backlash occurs in all rotary tables and exists between the worm and worm gear just as it does in a leadscrew, so it must be considered. In the case of this particular table it amounts to .2° to .3°. Setting the worm any closer to the gear will amount in excessive drag and wear. The smaller the diameter you are working with, the less the backlash error will effect you. When working on a diameter of 1" (25.4mm), the total backlash will be less than 0.002" (0.05mm), but at 4" (100mm), the error could be as high as 0.010" (.25mm). (See the "Maintenance" section on page 11 for instructions on adjusting the worm gear backlash and page 6 for the paragraph on setting the electronic backlash compensation.)

When the rotary table is used with the right angle attachment, backlash has to be considered in a different way if an "off balance" fixture is mounted. As the out-of-balance fixture is being lifted against gravity, the backlash

remains normal, but after the fixture goes past top dead center, the off-balance fixture will pull the backlash to the opposite side. This could give you an error equal to the backlash. This is around .2° and must be considered. I realize this is an unusual occurrence, but it is a tough one to find, which is why I mention it. If you believe this is a possibility, hold the backlash in the correct direction after the move is complete and tighten the lock. Of course you could also add a counterbalance to eliminate this problem.

USING THE MILL AND ROTARY TABLE AS A LATHE

A machinist working with miniature tools may find it useful to use the rotary table to turn large diameter parts. The CNC table can be set to run continuously and diameters can be formed with end mills rather than lathe tools.

LOCKING THE TABLE WHEN MAKING A CUT

If you are using the rotary table to cut a gear, the table lock should be used during the cutting process; however, I don't believe it is necessary when cutting a small, fine pitch gear. As soon as you lock the table you stand a chance of forgetting to unlock it before attempting to advance the table. This would result in losing your place, because the stepper motor system has no way of recording whether or not it moved. When doing repetitive machine operations you have to be very methodical. Let your mind wander and you stand a good chance of screwing it up. If you make this type of screw-up, all is not lost if you took the time to write the exact handwheel setting down at the start so you can start over from exactly the same place. This is good insurance before starting a series of cuts.

PRECAUTIONS REGARDING HOT CHIPS AND COOLANT

Care should be taken to prevent hot chips from landing on the computer and burning into the keypad. Also, the electronics can be damaged if the motor is flooded with coolant. Sherline's one-year warranty does not cover this kind of damage because it is caused by misuse. The extension should be used to keep the computer at a safe distance.

MAKING ALLOWANCES FOR CUTTER DIAMETER

A close look at Figure 5 will start making you aware of the complexities of working with a rotary table. Unless you are doing a hole layout, you very seldom can work with the angles and dimensions on your drawing because of the cutter diameter.

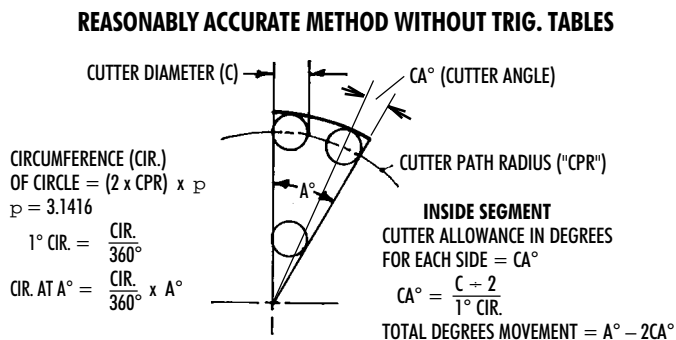


FIGURE 5—A demonstration of CPR or Cutter Path Radius.

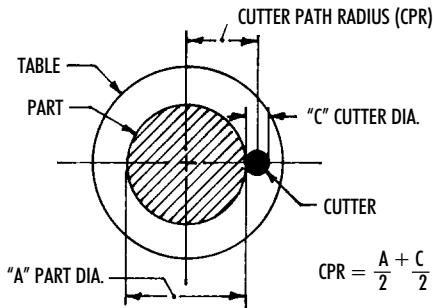


FIGURE 6—Cutter machining outside of part.

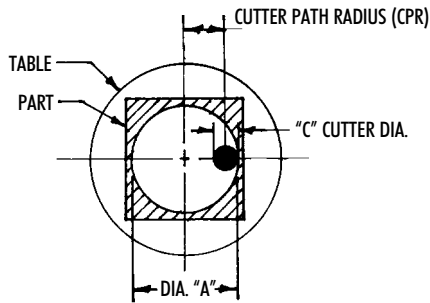


FIGURE 7—Cutter machining inside of part.

Figures 6 and 7 show the relation of cutter and part. Start considering what I refer to as CPR, which is where the center of the cutter is from the center of the rotary table.

The next problem to be aware of is why the rotary table must be offset to cut segments. Study Figure 9 and it becomes obvious that allowing for the cutter diameter at one end of the segment will not make any correction at the other.

EXAMPLE: CUTTING A WHEEL WITH SPOKES

When one of our customers purchases his first metal cutting tool, it is usually a lathe, and somewhere in that customer's mind is a brass canon he has been wanting to build. When a customer buys his first rotary table, chances are he either wants to drill hole patterns, which shouldn't require any instructions, or he wants to make some kind of wheel with spokes in it. Therefore, I will describe how to "accurately" cut a wheel with spokes. I realize that in most cases it is not necessary to work to this degree of accuracy to do a job of this nature, but to accurately make a precision part of this type is what a rotary table is all about. In most cases, I will leave you to your own common sense as to the depth of cuts and how much to leave from roughing and finish cuts. Remember, I have never seen a part scrapped from taking too light of a cut..

Make an accurate drawing at the start showing offsets and cutter paths (similar to Figure 10). The offsets can be calculated as shown in the sample in Figure 10.

REMEMBER...the rotary table center must be precisely located below the spindle when you start. Only one half of the segment may be cut from the calculated point, which is why only one half of the spoke width is considered. Look at the drawing again and be sure you truly understand why you can only cut one half of the segment before proceeding, or your chances for success will be dismal.

Now we have the offsets calculated and the rotary table

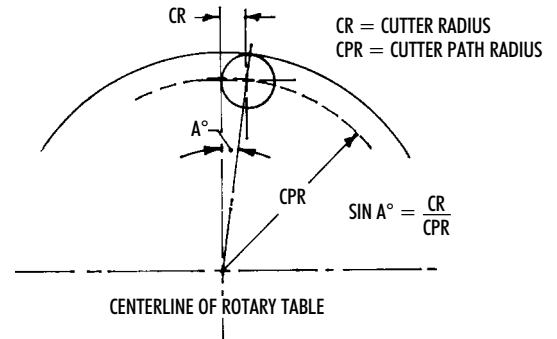


FIGURE 8—This example shows how easy it is to allow for the cutter diameter using trigonometry.

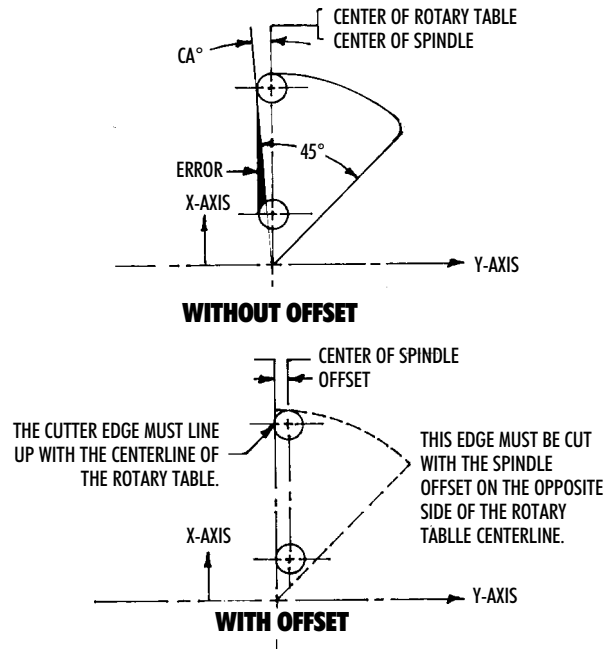
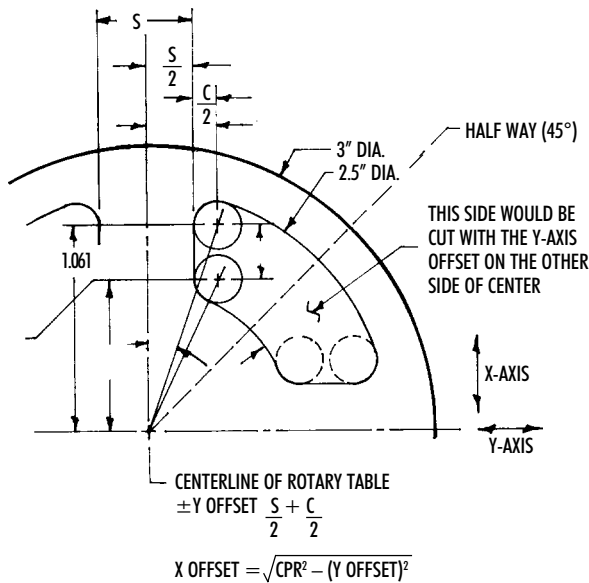


FIGURE 9—Offsetting the rotary table to cut segments "indicated in" in relation to the spindle. We move the X-axis the amount of the offset, moving the table to the left. Be sure to consider the backlash, and it may also be prudent to allow for roughing and finish cuts. Now move the Y-axis and the Y offset in (towards the column). This will allow the first half of the segment to be cut so that it looks like the diagram. Assuming the part is properly clamped to the rotary table and held in such a way that you can't inadvertently cut into the table, it's time to start. The example has four equal segments, which means a spoke will be cut every 90°; therefore, a lot of confusion can be eliminated if you start with your table at 0° (see Figure 8). The center of the spokes will now lay out at 0°, 90°, 180°, and 270°, and the halfway points will be at 45°, 135° etc. Allowance for the cutter was taken care of when the offsets were calculated. It is not necessary to calculate the value of angle "A" or other angles because you are only cutting half of the segment at a time.

A good rule now is to take a very light cut (.001") and convince yourself everything is correct. The real trick of machining is to do something you have never done before the "first time", and you can't be too careful. A one-minute check versus three hours or more to start over makes this a good investment in time. The cut along the spoke is



CUT OUTSIDE

GIVEN: S (SPOKE WIDTH) = .5
 CPR (CUTTER PATH RADIUS) = 1.250 - .125 = 1.125
 C (CUTTER DIAMETER) = 0.25

$$\pm Y \text{ OFFSET} = \frac{S}{2} + \frac{C}{2} = \frac{.5}{2} + \frac{.250}{2} = .375$$

$$X \text{ OFFSET} = \sqrt{CPR^2 - (Y \text{ OFFSET})^2} = \sqrt{1.125^2 - .375^2} = \sqrt{1.266 - .1406} = 1.061$$

CUT INSIDE

$$CPR = .750 \text{ (HUB RADIUS)} + .125 \text{ (CUTTER RADIUS)} = .875$$

$$X \text{ OFFSET} = \sqrt{CPR^2 - (Y \text{ OFFSET})^2} = \sqrt{.875^2 - .375^2} = .791$$

$$\text{DISTANCE BETWEEN INSIDE AND OUTSIDE OFFSETS} = 1.061 - .791 = .270$$

FIGURE 10—Drawing and calculations for cutter paths. accomplished by moving only the X-axis back and forth using the calculated points until you get through the part. Again, I remind you it may be wise to take a roughing cut first. Sometimes an undersize (resharpened) end mill is a good way to rough cut. Then change to a new end mill for finish passes. This allows the same handwheel number used for roughing and finishing.

The rotary cuts are made with the X-axis in its proper position, and the table rotated counterclockwise. One of the really neat things in machining happens when using a rotary table to feed work into an end mill, and I believe it comes about because of the slow and precise feed that can be obtained. If a hole you're cutting requires a bottom, great finishes can be had from end mills and rotary tables. The rotary part of the segment only needs to be moved slightly past the half way point, for the remainder of the segment will be cut with the Y-axis offset moved out from the column and the table rotated in a clockwise direction.

It is quicker to cut the first half of all four segments, then move the Y offset and complete the segments. If you are going to try something like this for a first project, check your entire plan out with .001" cuts and be positive you are correct before making cuts that could scrap your part. (See Figure 11.)

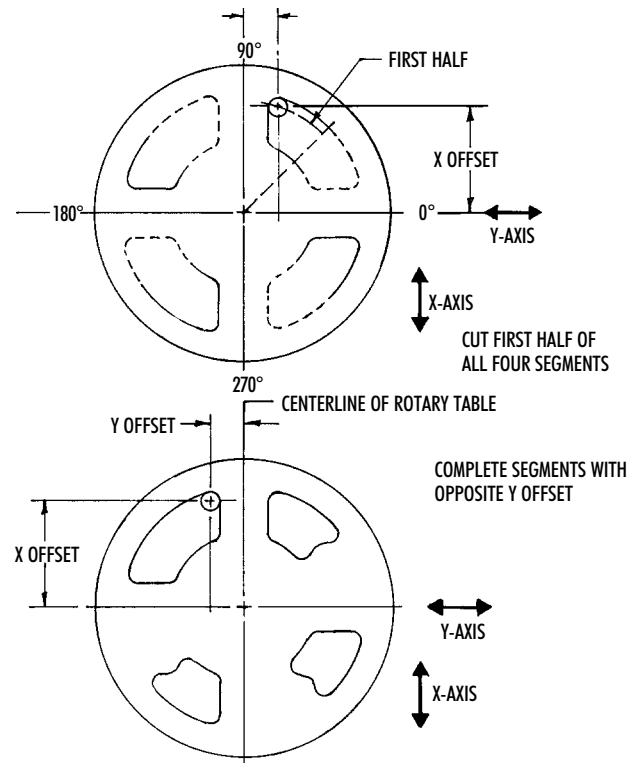


FIGURE 11—Completing the spokes of a wheel.

CUTTING GEARS WITH A CNC ROTARY TABLE

I am going to leave it up to you to determine when you know enough about gears to try to produce one. One of the best sources for information on gears is *Machinery's Handbook*. Gears are built to a rigid set of rules, and they are more complex than you might imagine.

I will only try to explain how to cut a simple, low-tolerance gear. You will also have to determine the blank size, depth of cut, RPM of the spindle and so on. If you successfully cut a good gear on your first attempt, be very proud of yourself. It can be frustrating if you are not organized.

Gears can be cut using a rotary table with a reasonable amount of precision. In many cases, gears—even inexpensive ones—are very precise. Gears are usually produced by "hobbing". This method uses a cutter that is similar to a worm gear. The teeth are generated with both the cutter and the blank turning. In fact, the process looks just like a worm gear running. Methods like this produce perfectly shaped teeth that are perfectly spaced. It may be theoretically possible to produce a perfect gear one tooth at a time, but it is difficult. Keep in mind, however, that the level of perfection required in a gear is related to how much power it will be expected to transmit. Gears transmitting a lot of power must be made to much closer tolerances than those driving the hands of a clock, for example. I suggest you stick with relatively low performance gears for your first few projects.

Cutters can be purchased that will produce a fairly good tooth form, but they are expensive and have a very limited range. (See the section on gear cutters on page 12.) A cutter can be ground that works like a fly cutter. Use our P/N 3217 for this. A 1/4" lathe tool blank is provided which fits this holder. Use the damaged gear you are replacing

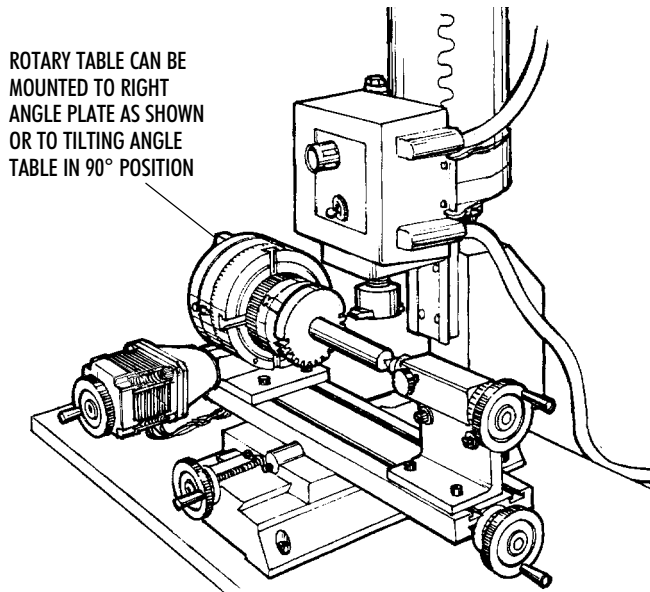


FIGURE 12—A sample setup for cutting a gear. A right angle attachment supports the rotary table in the 90° position while an adjustable tailstock is used to support the end of the long shaft. A Sherline gear tooth cutter holder (P/N 3217) holds a custom-ground 1/4" HSS cutter.

for a shape reference when grinding the tip of the cutter. The corners on a bench grinder wheel are used to generate the shape on the tool blank. At first it may seem almost impossible to do this, but it is not. Just keep checking the tool to a gear that can be used for a gauge by holding the two up to a light source. You'll find that the final grinding is done by "feel". Lathe tool bits are cheap and available, so it is a process worth learning. When the tool is mounted in the holder, don't allow it to stick out any more than necessary. Figure 12 shows a typical setup. A tailstock isn't always necessary. Remember that the gear blank must run true before starting. The book I wrote called *Tabletop Machining* has a chapter about cutting gears that offers more details for anyone interested in learning more about this type of work.

CALCULATING YOUR CUTS

This is where the computer has taken the drudgery out of cutting gears. No longer do you need index plates or complex calculations to cut gears, and your effort can be directed towards a quality cut. I don't want to get involved in every calculation used in cutting gears, but there are a couple of things you should know when cutting standard gears.

The pitch of a gear is determined by how many teeth will fall on the circumference with a diameter of 1". An example would be a 24-pitch gear would have 24 teeth with a pitch diameter of 1" The OD of this gear would be equal to the pitch diameter to the number of teeth you wish to cut plus 2. To calculate this diameter all you have to do is divide the amount of teeth you wish to cut by the pitch of the gear. 26 divided by the pitch 24 and you get 1.0833, which will be the OD of a 24-tooth (24T) gear with a 24 pitch (P) in inches. What could be simpler? This system works so well you will find that many of the metric gears that are

called a metric module use this system and then convert the dimensions to metric.

With the computer calculating the exact movement of the rotary table and a correct diameter gear blank mounted on the table all you have to know the depth the cutter has to cut to produce a good gear on your first try. To determine the depth of the cut all you have to do is divide the pitch of the gear into 2.157. To complete the information needed to produce our 24T 24P gear you divide 2.157 by 24 which calculates out to .0899. It doesn't make any difference whether you are cutting a pinion gear with 14T or a gear with 150T the calculations are this simple.

Calculating the dimensions and cutting the teeth are two different things. The quality of gears are really determined by the concentricity of the teeth in relation to the shaft they rotate on, the tooth form and the machined finish of the teeth, and the proper distance between centers of the gear it is going to mate with. The gear blank has to be supported properly to insure a good finish during machining. Unless the gear is a very fine pitch you should roughing and finishing cuts which can be easily accomplished with the CNC rotary table.

MAINTENANCE

Keep oiled to prevent rust. A few drops in the oiler before using will eliminate table wear. The worm gear is greased at the factory.

Moving the worm housing to compensate for wear can eliminate worm backlash. From the bottom of the rotary table, loosen **one** of the two socket head cap screws holding the worm housing to the table base. Lightly tap the housing toward the table with a plastic mallet to push the worm a little tighter into the gear teeth on the table. When backlash is less than .2°, retighten the screw.

A NOTE ON MOUNTING THE RIGHT ANGLE ATTACHMENT

On the side of the worm housing (see exploded view on next page) are four holes which are used to mount the optional right angle attachment, P/N 3701. They go all the way through the part. In order to keep dirt and chips from entering the worm housing, setscrews have been installed in the holes. Before the right angle attachment can be mounted, these setscrews must be removed. Be sure to reinstall them when the right angle attachment is removed.

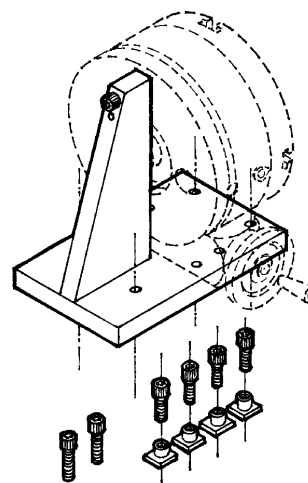


FIGURE 13—Right angle attachment

ADJUSTABLE RIGHT ANGLE TAILSTOCK, P/N 3702

(See Figures 12 and 14.) Because of tolerance build-up, it would be just about impossible to offer a tailstock that was perfectly on center with the rotary table/right angle attachment combination. The solution offered here is a modification of our standard tailstock, which allows it to

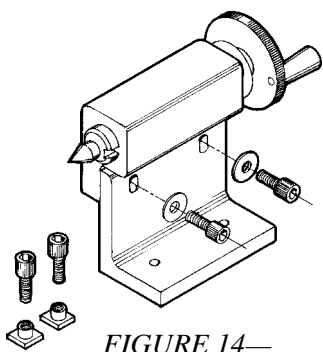


FIGURE 14—
Adjustable right
angle tailstock

be adjusted to exactly line up with the center of the rotary table in order to allow for perfect alignment between the rotary table and the tailstock while holding long parts between centers. The base is attached to the mill table with cap screws and T-nuts. The two socket head cap screws go through elongated slots in the side of the right angle piece and allow for minor

adjustments in height when making your setup.

PURCHASING GEAR CUTTERS

Gear cutters may be purchased from large, industrial tool suppliers. One of the best known is Manhattan Supply Company in New York. They may be reached at (800) 645-7270 or you may go to their web site at www.msdirect.com to order their catalog or CD-ROM. For example, on page 540 of their 1999 catalog, an involute gear cutter with 14-1/2° pressure angle and a 24 pitch in a #3 cutter is P/N 03192432 and lists for \$20.70 (1999). They carry a complete selection of 14-1/2° and 20° HSS gear cutters in stock.

RANGE OF CUTTERS

CUTTER #	CUTS GEARS FROM
1	135 Teeth to rack
2	55 to 134
3	35 to 54
4	26 to 34
5	21 to 25
6	17 to 20
7	14 to 16
8	12 to 13



FIGURE 15—14-1/2°
HSS involute gear cutter

Round gear cutters like the ones described above can be held on Sherline tools using Sherline's mill cutter arbors. They are available to hold 7/8" or 1" I.D. cutters and come in short (3/4") or long 1-3/4" standoff lengths. They have a #1 Morse taper with drawbolt and are designed to fit Sherline's headstock. Part

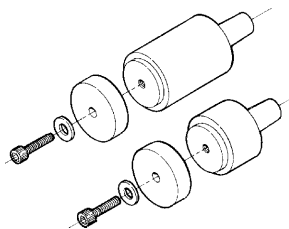


FIGURE 16—Arbors to
hold round gear cutters

numbers are: 3230—7/8" short, 3231—7/8" long, 3235—1" short and 3236—1" long.

Clock gear cutters can be hard to find, but they are available from Hirschmann Antique Clocks, P.O. Box 194, Titusville, NJ 08560-0194. Their phone number is (609) 737-0800 and their fax number is (609) 737-0054.

PRECAUTIONS REGARDING MANUAL MODE

When hand cranking the handwheel in the manual mode, the stepper motor acts as a generator. If you crank the handwheel rapidly, there is a chance that the control box electronics could be damaged by the current generated. If the unit is to be used extensively in the manual mode, it is recommended that you disconnect the cable from the motor to the controller.

I have repeated some information from section to section, as I know some people don't read instructions from front to back. They just search for the part that answers their immediate question. So, if my instructions seem somewhat redundant, please forgive me. I could be living on a 60' yacht in the South Pacific if I could recover the money in scrapped parts I've had employees produce by cutting first and thinking later!

Joe Martin, President and owner
Sherline Products Inc.

SHERLINE REPLACEMENT PARTS ORDERS : (800) 541-0735
TECHNICAL ASSISTANCE (Bryan Mumford): (805) 687-5116

The Sherline CNC rotary table controller was designed by Bryan Mumford at Mumford Micro Systems in conjunction with Sherline Products, Inc. Thanks to John Wettrath and Joe Martin for advice and suggestions.

Bryan Mumford, Mumford Micro Systems
3933 Antone Road, Santa Barbara, CA 93110
Phone: (805) 687-5116
Fax: (805) 687-4905
bryan@bmumford.com
<http://www.bmumford.com>

USING A RISER PLATE ON SHERLINE MILLS

On page 14 we provide a drawing of a riser plate that will lift the rotary indexer enough to clear the mill handwheel on Sherline mills. Four mounting holes marked "A" are used to mount it to the mill table T-slots. If used on a non-Sherline machine, you may eliminate these holes. You may make the plate yourself from the drawing. Sherline will be offering the plate as an accessory should you wish to order one ready-made in the near future.

**SHERLINE P/N 8700 CNC Rotary Indexer
EXPLODED VIEW**

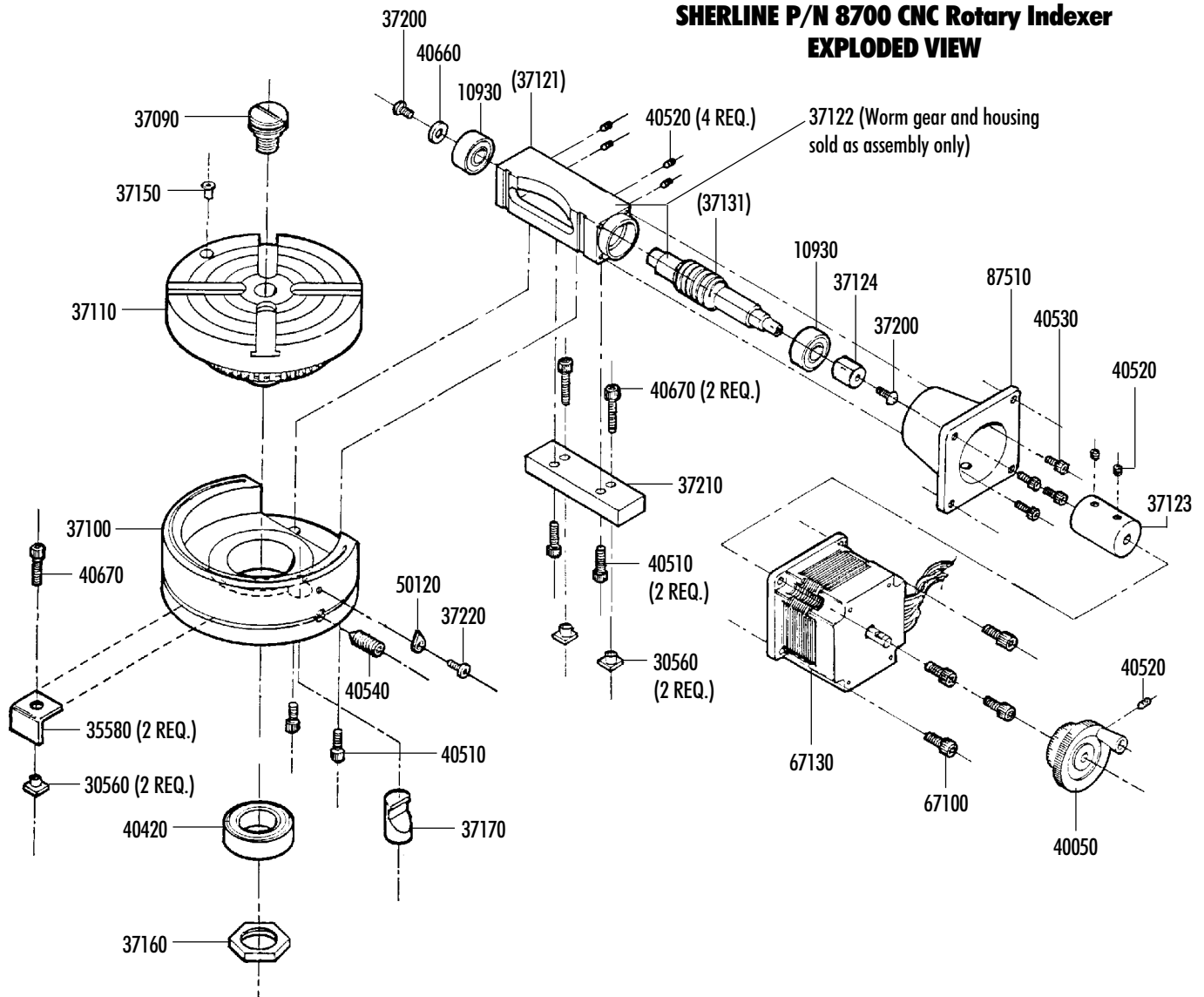


FIGURE 17—Exploded view

PART NUMBERS AND DESCRIPTIONS

PART NO.	REQ.	DESCRIPTION	PART NO.	REQ.	DESCRIPTION
10930	2	3/8" Bearing	37210	1	Hold-down tab
30560	4	10-32 T-nut	37220	1	6-32 x 1/4" button head socket hd. screw
35580	2	Hold-down clamp	40050	1	1-5/8" handwheel assembly
37090	1	Chuck adapter	40420	1	Headstock bearing
37100	1	Rotary table base	40510	4	10-32 x 3/8" Socket head cap screw (SHCS)
37110	1	Rotary table top	40520	7	10-32 x 3/16" cup point set screw
37121	(1)	CNC rotary table worm housing (Not sold separately)	40530	4	5-40 x 3/8" SHCS
37131	(1)	CNC rotary table worm shaft (Not sold separately)	40540	1	5/16-18 x 3/4" cone point set screw
37122	1	CNC rotary table worm housing assembly	40660	1	3/16" I.D. washer
37123	1	CNC rotary table coupling	40670	2	10-32 x 1/2" SHCS
37124	1	CNC rotary table coupling adapter	50120	1	Pointer
37150	1	Oiler	67100	4	8-32 x 3/8" SHCS
37160	1	Preload nut	67130	1	2 Amp, 100-oz., 23 frame size stepper motor
37170	1	Lock pin	87510	1	CNC rotary table stepper motor mount
37200	2	10-32 x 3/8" button head socket hd. screw			

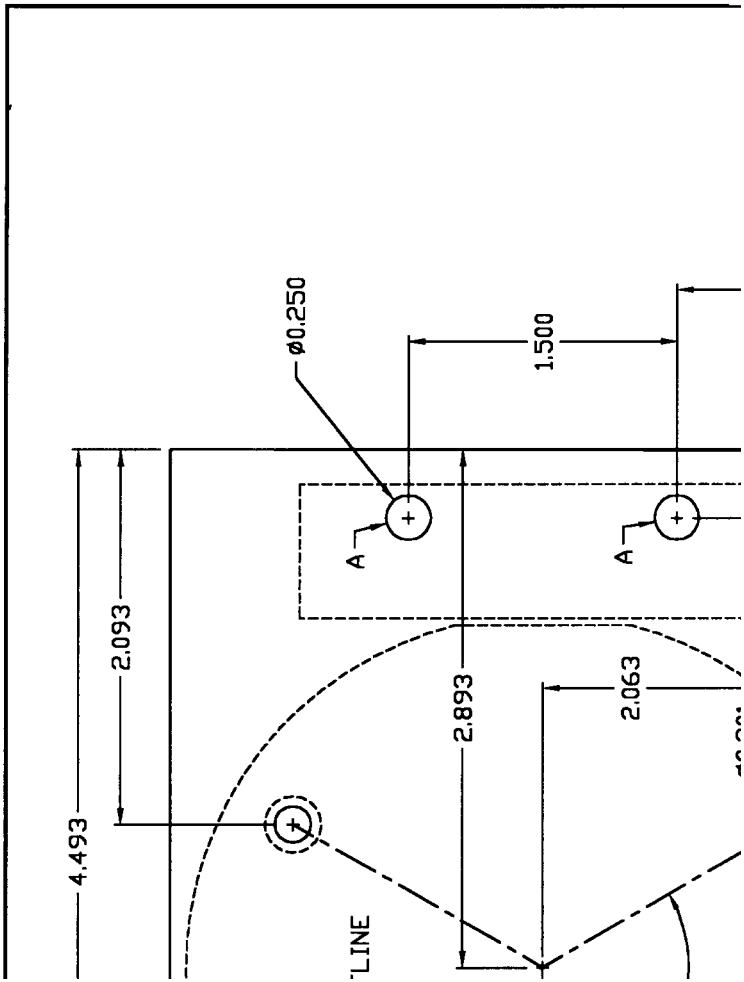


FIGURE 18—P/N 37511 riser block plans