

WORK PIECE TRANSFER BETWEEN MAIN AND SUB SPINDLE

Transferring a work piece from one spindle to the other is done with the B-axis that transports the sub spindle. Moving the sub-spindle onto the main spindle allows “handing-over” the work piece from one spindle to the other. Normally, machining is done on the main spindle at first then the part is transferred to the sub spindle for additional machining to be done on the back-end of the part.

The following aspects need to be considered for work transfer operations:

- **Chucking equipment on the sub-spindle.**
The sub-spindle that normally serves as the “Receiver” of the transferred part uses either a three-jaw chuck or a True-Length type collet chuck. No axial movement of the collet must occur while closing the chuck, such as is the case with a standard collet chuck. The use of compactly designed collet chucks is preferred. For example: Type 3-J DL, with reduced collet nose diameter is best. Larger chucks cause interference with turret and cutting tools during parts transfer.
- **Chucking equipment on the main-spindle.**
The main-spindle can use either a three-jaw chuck or a standard collet chuck, for most applications. The use of compactly designed collet chucks is preferred. For applications that employ the sub spindle for advancing (“pulling”) of bar stock, either a three-jaw chuck or a True-Length type collet chuck is required.
- **Non oriented, synchronized spindle rotation.**
This feature allows synchronizing the spindle rotation with both spindles engaged on the work piece at the same time. Synchronization can be done from spindle stopped condition. Both spindles operate in unison, at precisely synchronized rotation. This type of synchronization is applied typically for turning of long shafts that are clamped by the chucks at each end. Alternatively, it can be used for cutting off a part from the bar stock then transferring it to the sub spindle. Timing or orientation between the two spindles in this case is at random. (See details for parameter settings, below)
- **Oriented and synchronized spindle rotation.**
Synchronization of the spindle rotation angle on each spindle is done before commencement of synchronized rotation. This function establishes and maintains the rotation angle relationship between entities machined separately on the main spindle and on the sub spindle. The condition for using this feature is that only one spindle is connected to the work piece. The chuck on the other spindle needs to be opened, before synchronization can occur. (See details for parameter settings, below)

- **B-axis torque control functions.**
 - a) B-axis torque skip function. This function allows seating of the sub spindle chuck in axial direction firmly against the work piece to be transferred, before closing the chuck.
 - b) Cutoff confirmation. B-axis torque control function is used for checking the actual separation between work piece and bar stock after cutoff.

Parameter Settings related to Spindle Synchronization

- a) Setting the data of keep relay K0, bit 0 decides the type of spindle synchronization that is performed.
 - Non-oriented spindle synchronization:** **K0.0 = 1**
 - Oriented spindle synchronization:** **K0.0 = 0**
- b) Phase synchronization angle (orientation) is shifted by following system parameters:
 - Main Spindle:** System parameter **#4034-S1**
 - Sub Spindle:** System parameter **#4034-S3**

Data range for parameter setting: zero ~ 4096, positive or negative value.
 One full rotation (360 degrees)=4096 units. One unit equals 0.088 degrees.
 (360/4096=0.088 degrees) One degree equals 11.3636 units.

Setting the orientation angle for Spindle Synchronization

When a part is to be transferred from the main to the sub spindle, precise alignment with the jaws or collet chuck on the sub spindle may be required. For example: when gripping on a polygon shape with the sub-spindle chuck, the following procedure is used for checking and setting the synchronized orientation position.

1. Set keep relay 0.0=0
2. In handle mode, move the B-Axis with the sub spindle chuck as close to the face of the part. Both spindles must be allowed to rotate freely, without touching the part.
3. Execute following commands, either in MDI-mode or Auto-mode, single block:

M131	-Sub Spindle Chuck interlock bypass command
M169	-opens the sub spindle chuck
G97 S0 M203	-synchronizes orientation on both spindles by rotating each of the spindles at their respective orientation position, as set by parameter #4034. Both spindles are now locked in position by the spindle motor.

4. At this time, the synchronized orientation position can be checked. Alignment error is measured by use of the C-axis position display.
5. Set "Origin" to "H", on the "Relative" position display for the C-axis.
6. Switch to handle mode. The motor releases both spindles at this time. Do not touch or move the spindles. Activate the C-axis mode by pushing the C-axis button on the operation panel.
7. Find the angular mismatch between jaws and the work piece by rotating the C-axis until the sub spindle jaw lines up with the part.
8. Adjust data setting on parameter #4034, accordingly. Repeat steps 2 to 8 until perfect alignment is established.

Oriented spindle synchronization command

- Set Keep Relay 0.0 =zero.
- The jaws or collet of one of the two chucks must be opened before the spindle synchronization command. This will allow each spindle to perform orientation, independently, without being connected to each other by the work piece.

The following series of commands are used in the order as shown when synchronizing the spindles:

M131	Sub Spindle Chuck interlock bypass command
M169	opens the sub spindle chuck
G97 S1000 M203 (M204)	Synchronizes spindles at 1000 RPM with simultaneous acceleration or deceleration.

Synchronized spindle stop command

When both spindles are running in synchronized mode, it is possible to do a synchronized stop. Both spindles come to a stop, synchronously. The synchronized spindle stop command is used only when both spindles are engaged with the work piece.

M205	Synchronized stop command
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Non- oriented spindle synchronization command

Set Keep Relay 0.0=1

Keep relay is set 1 for applications where machined entities on each spindle have no relationship concerning rotation angle to each other. Synchronization command is possible with both chucks engaged with the work piece.

G97 S1000 M203 (M204)	Synchronizes spindles at 1000 RPM with simultaneous acceleration or deceleration.
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Caution with G96 in Spindle Synchronization Mode

The G96-command may cause erratic acceleration or deceleration when machining is done on relatively small work diameter. This is typically the case during cutoff operation where the cutoff tool is moved to X0. Consequently, slippage between the sub spindle chuck and the work piece may occur, when both chucks are engaged with the work piece. Slippage causes error in angular relationship between entities that are machined on each spindle separately.

It is best to do the cutoff operation as follows:

1. Position the cutoff tool a little above the bar stock diameter with the Z-axis at the correct position for cutting off.
2. Start-up the main-spindle in G96-mode and move the B-axis close to the part.
3. Cut a groove to the smallest possible part diameter, leaving enough material so that the part will not break away from the bar stock. At the bottom of the groove, slightly retract the tool. ("U0.01)
4. Synchronize both spindles in G97-mode at the desired RPM. Then gripping the part with the sub spindle, completing the cutoff operation.

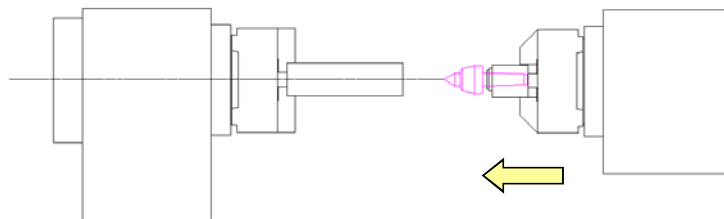
For reliable operation in spindle synchronization mode, the spindle speed should be kept between 60 and 2500 RPM.

Torque Control Functions for B-axis

The table below shows special G-codes that apply for PUMA 1500SY, 2000SY and 2500SY models, only. These G-codes command B-axis torque control functions. G-codes call the sub programs as registered in NC-parameter tables # 6050 through # 6059.

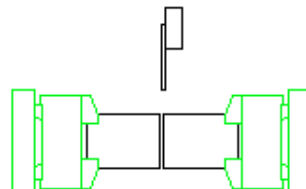
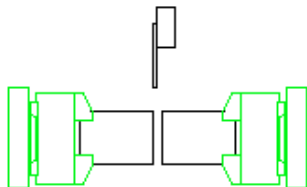
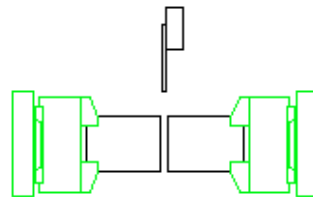
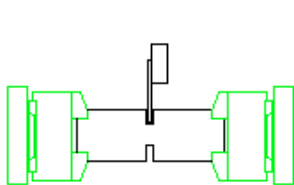
Live center support with Sub Spindle

G-Code	Description
G300	<p>Live-Center Support with B-axis “ON” G300 Calls program O9010</p> <p><u>Program Example:</u> Attach a suitable work support device to the sub spindle, such as a live-center. Then insert the following commands into the program:</p> <ol style="list-style-type: none"> 1. G0 B___ ---Position the B-axis within 0.1” to 0.2”, clear of the end of the work-piece that is to be supported. Synchronize the spindle RPM for main and sub spindle, if desired. 2. G300 B-200. –G300 calls the sub program. The “B”-command sets the torque for the B-axis. “B-200.” Means 20% of the available torque applied on the B-axis in “minus” direction. The B-axis now commences to move in negative direction, pushing the live center onto the work, applying the specified torque. 3. X__Z__ Start the machining operation with live center in place. 4. G301 --G301 Calls the sub program O901, canceling the torque control mode. This command is required before positioning the B-axis.
G301	<p>Center Support “OFF” (cancel) G301 Calls program O9011, canceling the torque control function.</p>



Cutoff Confirmation

G-Code	Description
G350	<p>Cutoff confirmation G350 Calls program O9011 Use the cutoff confirmation command for cutoff operation in combination with work piece transfer from main to sub spindle only.</p> <p>Program Example: Upon separation of the work-piece from the bar stock, retract the cutoff tool with the X-axis, so that the tool clears the OD of the bar stock. Now, insert the following commands into the program:</p> <ol style="list-style-type: none"> 1. G350----Calls the sub program O9012. The B-axis will now attempt to close the gap that exists between the bar stock and the work piece, automatically. When the movement of the B-axis is less than 0.04", an alarm occurs, signaling that the work piece has not been separated from the bar stock. When the movement is greater than 0.04, no alarm will occur. 2. G4 U0.5---A dwell time of 0.5 seconds is required. 3. G0 B___ Positioning command, clearing the sub spindle out of the way.



Sample Program1: Spindle Synchronization, Cutoff and Parts Transfer to Sub Spindle

Program includes torque-skip function.

N1400(CUTOFF & TRANSFER)	
G0G40G80G99	
G50S3000M31	M31= main spindle interlock bypass
G53 B0M131	M131=sub spindle interlock bypass
G30U0W0	
T0303	
M169	M169=open sub spindle Chuck
G97S1000M203	M203= spindle synchronization-command
G0X3.Z-2.250S1500	Positioning the cutoff tool at cutoff position
G0B-15.2 S2000	Step up rpm & bring sub chuck to within 0.1" to face of part
M86	Torque Skip data setting
G31G98B-15.8 0 F30.	Command the B-axis to move by 0.1" past the point where the shoulder on the chuck bottoms out on the face of the part.
G99M168	M168= close sub chuck
M87	Torque Skip data setting cancel
G0X2.1M8	Final approach with cutoff tool
G1X0 F.002	Cutoff
	Part in sub spindle is now separated from bar stock. Sub spindle axial pressure releases, pushing slightly against cutoff tool.
M5	Stop main spindle. This twist-off any remaining material
G0B-3.5	Retract sub spindle
G0X3.M9	Retract cutoff tool
G30U0W0	
M105	Stop sub spindle
M1	

Sample Program 2: Spindle Synchronization, Cutoff and Parts Transfer to Sub Spindle

Program includes torque-skip function, pickup position check and cutoff confirmation G350.

N200(CUTOFF & TRANSFER)	
G0G18G40G99	
G53B0	
G30U0	
G30W0M131	Interlock bypass
T0303	
G0Z-2.895M114	Move Z at cutoff position Clean sub spindle chuck
G97S1275M3X2.1	Start main spindle, move X to part
X1.2	
G0B-14.986(1-INCH CLR.OF FACE)	Move B close to part
G96S400M8	CSS & coolant on
G1G99X.25F.002	Pre-cutoff
U.02	Tool release
G97S1500M169	Fixed spindle rpm
M203	Synchronize spindles
G4U1.	
G0B-17.386(.1CLR)	B within 0.1" clear of shoulder
M86	Torque skip on
G31G98P99B-17.9F5. (B-17.811)	B to to skip position
G99M87	Torque skip off
WHILE[#5104NE0]DO1	Wait until B quits moving
END1	
#100=0	Set alarm flag at zero
#524=#5024	Store the current machine Coordinates of the B-axis.
#525=#524+17.811	Calculate the difference between actual and theoretical pickup position.
#525=ABS[#525]	Make it a positive number
IF[#525GT0.005]GOTO205	Check the tolerance. Skip to N205 if not in tolerance. If within tolerance, do next line.
M168	Close the sub chuck
M8	
G1G99X-.01F.002	Cutoff all the way
X2.1F.01	Feed the tool back out (B-axis may exert pressure onto the tool)
G0X4.	Clear the tool away from stock

N206G350(CUTOFF CONFIRMATION)	B axis attempts to close the gap left by the cutoff tool. If it cannot move at least 0.05", alarm occurs.
G4U.5	Must have dwell command here
GOTO206	Skip the alarm flag
N205#100=1	Set the alarm flag
N206G53B0M105	Retract B axis
G30U0M9	Retract X
G30W0M5	Retract Z, main spindle off
IF[#100NE1]GOTO208	If alarm flag not set, skip to N208
#3000=1(PICKUP NO GOOD)	Alarm condition. #525 shows the deviation from the expected pickup position
N208M1	

Bar Feed Operation

M-codes used for the bar feed operation

M5 Stop the spindle
 M9 Stop the coolant
 M31 Chuck interlock bypass (allows operation in auto mode with chuck open)
 M69 Open the chuck
 M50 (M51) Bar-push command (M50 or M51 depending on wiring connections)
 M68 Close the chuck

Bar feed sub programs

Using separate sub-programs that contain all the necessary commands for the bar feed operation is recommended. (See sample programs O7000 and O7001 shown below)

Bar Stopper (Tool for stopping the bar)

When a SERVO-type bar feeder is at hand, ordinarily no bar stopper is required. However, in some cases the user may choose to use a bar-stopper anyway for improved accuracy and reliability. When a bar stopper is used, the bar-feed program needs to be modified, accordingly.

Top cutting the front face of a new bar

The front end-face of a new bar in some cases may have to be cutoff or machined separately from the normal machining operation. In this case, the top cutting can be included in the bar-reload sub program if desired.

End of bar-signal

The bar feeder sends a signal to the NC at the time when there is not enough material left for the next bar-advance. The bar-end signal operates the **Block-Skip Switch “/ 2”** on the NC. This feature allows the NC to distinguish between normal bar feed out and bar reload operation. When M50 is commanded at the time the bar-end signal is “ON” the bar feeder ejects the remnant material first, then automatically loads a new bar. The bar stopper must not block the front of the spindle at this time.

Timer Setting (M50/M51 time-out)

Timer **T32** in the PMC-Parameters sets the time-out for the M50 & M51 function. Standard setting is 20 seconds. When the bar feed out or bar reload, time exceeds the set time an alarm occurs.

Inserting the bar feed command into the machining program

In a bar-machining program, the bar feeding operation is done typically after all machining operations have been completed. The bar feed command is normally inserted into the machining program near the bottom.

Bar Feed Sub Program Call

N7000 M98 P7000 (Bar feed sub program call.) Insert this command near the bottom the machining program.

Bar Reload Sub Program Call

/2M98 P7001 (Bar reload sub program call.) This command is needed only for applications where a bar-stopper is used or when top cutting is done. Insert this command into the bar feed sub program O7000.

Program Examples for use with bar feeder

Example 1: Bar Feed Sub Program, for use without bar stopper or without top cutting.

O7000 (Bar Feed)

M5	(Spindle stop)
M9	(Coolant off)
M31	(Chuck Interlock-bypass command)
M69	(Open chuck)
M50 (M51)	(Bar-push command)
M68	(Close chuck)
M99	(Return to Main Program)

Example 2: Bar Feed Sub Programs, for use with bar stopper, without top cutting.

O7000 (Bar Feed with bar stopper)

M5 (Spindle stop)
M9 (Coolant off)
T0707 (Bar stopper)
M31 (Chuck interlock-bypass command)
M69 (Open chuck)
/2 M98 P7001 (If bar-end, go to reload program)
G0 *Z1. (Positioning Z)
X0 (Positioning X)
G1G98 *Z0.02 *F100. (Feed to bar stop position)
M50(M51) (Bar-push command)
M68 (Close chuck)
G0 W1. (Retract Z)
***X6.** (Retract X)
M99 (Return to Main Program)

O7001 (Bar Reload)

M50(M51)
M68
M99

Note Please modify the Z-coordinates and feed rate shown above to suit the application.

Example 2: Bar Feed Sub Programs, for use with bar stopper, with top cutting.

O7000 (Bar Feed with bar stopper)

M5 (Spindle stop)
M9 (Coolant off)
M31 (Chuck interlock-bypass command)
M69 (Open chuck)
/2 M98 P7001 (If bar-end, go to reload program)
T0707 (Bar stopper)
G0 *Z1. (Positioning Z)
X0 (Positioning X)
G1G98 *Z0.02 *F100. (Feed to bar stop position)
M50(M51) (Bar-push command)
M68 (Close chuck)
G0 G99 W1. (Retract Z)
X6. (Retract X)
M99 (Return to Main Program)

O7001 (Reload & top cut)

M50(M51)
M68
M68
T0505 (Cutoff tool)
G96 S500 M3
G0 Z-.5 M8
X1.1
G1 G99 X-.02 F.002
G0 X6. M9
Z1. M5
M99