

TORMACH® 770M^x



IMPORTANT! VERIFY YOUR SERIAL NUMBER! This manual is only for machines with serial numbers beginning with **ML**.

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To the Reader

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IMPORTANT INFORMATION: PLEASE READ FIRST

VERIFY YOUR SERIAL NUMBER

This manual is for the EtherCAT 770MX with serial numbers beginning with **ML**. On the machine, the serial number plate is on the side of the electrical cabinet, near the Main Disconnect switch.

If your serial number begins with **MF**, you'll need the previous version of this manual ([UM10587](#)).

If you're not sure which machine you have, we can help. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

INSPECT THE ITEMS DELIVERED

Before installing your machine, carefully inspect all delivered items. Complete the following steps upon receiving your shipment to ensure that everything is in proper condition and that any issues are promptly addressed.

1. Inspect the item(s):
 - Photograph any damage that may have occurred during shipping.
 - Note any damage on the delivery receipt before signing for the shipment. If there is extensive visible damage to the machine, refuse to accept the shipment.
 - Verify the received goods against the packing list.If there is any damage or shortages, you must contact Tormach within 30 days of receipt. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.
2. If there are any items that have not yet been delivered, we recommend waiting until you've received all shipments to begin installing the machine. Depending on the product and options ordered, the system may arrive in one or more shipments of:
 - Accessories (if applicable)
 - Machine



Note: The machine system and large accessories are sent by freight carrier. Smaller accessories may be sent by parcel service.

SAVE THESE INSTRUCTIONS!

This document contains important safety warnings and operating instructions for your machine. Before operating this machine in any way, you and all other operators must read and understand all instructions. If you don't, there's a risk of voided warranty, property damage, serious injury, or death. Keep these instructions with your machine so that they're readily accessible.

PURPOSE AND SCOPE OF THIS DOCUMENT

This document is intended to provide sufficient information to allow you to install, configure, and use your machine. It assumes that you have appropriate experience and/or access to training for any computer-aided design or manufacturing software for use with the machine.

GETTING HELP

We provide no-cost technical support through multiple channels. The quickest way to get the answers you need is normally in this order:

1. Read this document.
2. Read related documents and watch related videos at tormach.com/support.

3. If you still need answers, gather the following information so that we may help you as quickly as possible:
 - Your phone number, address, and company name (if applicable).
 - Machine model and serial number, which are located on the side of the electrical cabinet, next to the Main Disconnect switch.
 - The version of PathPilot that you're running.
 - Any accessories that you have for your machine.
 - A clear and concise description of the issue.
 - Any supporting media and information that you can share with us. For example, you could:
 - Analyze what might have changed since the machine last worked correctly.
 - Record a short video.
 - Take a picture of a part.
 - For software, share log data .zip files, screen captures, or program files.
For information, see "Share Log Data .zip Files" (below).
 - From the PathPilot interface, on the Status tab, record any available information.
 - Use a digital multimeter for voltage readings.
4. Once you've gathered the information in Step 3, contact us in the following ways:
 - a. Create a support ticket: Go to tormach.com/how-to-submit-a-support-ticket
 - b. Phone: (608) 849-8381 (Monday through Friday, 8 a.m. to 5 p.m. U.S. Central Standard Time)

tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

LIABILITY DISCLAIMER

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This document provides guidance on safety precautions and techniques, but because the specifics of any one workshop or other local conditions can vary greatly, we accept no responsibility for machine performance or any damage or injury caused by its use. It's your responsibility to verify that you fully understand the implications of what you're doing and comply with any legislation and codes of practice applicable to your city, state, or nation.

SHARE LOG DATA .ZIP FILES

The controller keeps log data on how the machine has been working, which you can export as a .zip file. This information helps us troubleshoot software situations much faster.

To share log data .zip files:

1. Put a USB drive into the PathPilot controller.
2. From the PathPilot controller, on the **Status** tab, select **Log Data**.
PathPilot creates a file called **logdata_[TODAY'S-DATE].zip**, and saves it on your USB drive.
3. Remove the USB drive from the controller. Create a support ticket with Tormach Technical Support at

IMPORTANT INFORMATION: PLEASE READ FIRST.....	3
SAFETY.....	19
1.1 Intended Use	20
1.2 Machine Standards	21
1.2.1 American National Safety Institute (ANSI).....	21
1.2.2 Occupational Safety and Health Administration (OSHA).....	21
1.3 Safety Overview.....	22
1.3.1 Safety Messages.....	22
<i>Personal Injury.....</i>	22
<i>Property Damage.....</i>	22
1.3.2 Safety Decals.....	22
<i>On the Electrical Cabinet Door.....</i>	22
<i>Next to the Main Disconnect.....</i>	23
<i>On the Spindle Nose.....</i>	23
1.3.3 Information Decals.....	23
<i>Serial Number Plate.....</i>	23
1.4 Machine Safety.....	25
1.4.1 General Shop Safety.....	25
1.4.2 Operational Safety.....	25
<i>General.....</i>	25
<i>Tooling.....</i>	26
<i>Workholding.....</i>	26
1.4.3 Electrical Safety.....	26
1.5 Noise Exposure.....	28
ABOUT YOUR MACHINE.....	29
2.1 Machine Specifications.....	30
SITE REQUIREMENTS.....	33
3.1 General Site and Space Requirements.....	34
3.1.1 Site Requirements.....	34
3.1.2 Space Requirements.....	34
3.1.3 Operator Workstation Reference.....	34
3.2 Electrical and Power Requirements.....	36
3.2.1 Electrical Requirements.....	36
3.2.2 Power Requirements.....	36
3.3 Air Requirements.....	37
3.4 Space Planning Drawings.....	38
3.4.1 Space Planning.....	39

TABLE OF CONTENTS

<i>Front/Right Views</i>	39
<i>Top View</i>	40
3.4.2 Minimum Transport Height	41
3.4.3 Table Clearance	42
3.4.4 Table Details	43
INSTALLATION	45
4.1 Before You Begin	46
4.2 Installation Tools and Items	47
4.2.1 Required	47
4.2.2 Optional	47
4.3 Move the Pallet	48
4.4 Self-Assembled Installation	49
4.4.1 Unpack the Machine Crate (Self-Assembled)	49
4.4.2 Unpack the Stand Crate	49
4.4.3 Lift and Move the Machine	51
<i>Required Tools</i>	52
<i>Before You Begin</i>	52
<i>Assemble the Lifting Bar Kit</i>	52
<i>Connect the Machine for Lifting</i>	53
<i>Lift the Machine</i>	53
4.4.4 Set Up the PathPilot Operator Console	54
4.4.5 Install the Enclosure	54
<i>Before You Begin Assembly</i>	55
<i>Required Tools</i>	55
<i>Unpack the Enclosure Crate</i>	55
<i>Install the Chip Pans</i>	56
Prepare the Sealant	56
Apply Sealant and the Install Chip Pans	56
<i>Install the Enclosure Panels</i>	56
Install the Left Rear Panel	56
Install the Left Side Panel	57
Install the Left Front Panel	57
Install the Enclosure Splice Plate	57
Install the Right Rear Panel	57
Install the Right Side Panel	58
Install the Right Front Panel	58
Install the Left Top Panel	58
Install the Right Top Panel	58
Install the Upper Front Panel	59
Install the Front Lower Panel	59
Install the Rear Splash Shield	59
<i>Install the Front Doors</i>	59
Install the Linear Rail Assemblies	59
Install Door Assemblies	60

Install the Door Latch	61
Install the Side Windows	62
Install the Floodlights	62
Install the Access Panel	62
Install the Stainless Steel Wear Guard	63
Use the Maintenance Labels	64
Replace the Windows	64
Mount the Operator Console	64
Apply Sealant to the Enclosure	65
Prepare the Enclosure	65
Tape the Seams	65
Prepare the Sealant	66
Apply Sealant	66
Cure and Test	66
Install the Air Gun	66
4.4.6 Install the Oiler	67
Make Automatic Oiler Connections	68
Make Manual Oiler Connections	68
Set Up the Manual Oiler	68
4.5 Factory-Assembled Machine Setup	69
4.5.1 Unpack the Machine Crate (Factory-Assembled)	69
4.5.2 Connect the Air Gun	71
4.5.3 Connect the Coolant System	71
4.5.4 Mount the Operator Console	71
4.5.5 Set Up the Automatic Oiler	73
Specify the Interval Time	73
Specify the Actuation Time	73
4.6 Verify the Installation	74
4.6.1 Power on the Machine	74
4.6.2 Verify Axes Function	75
4.6.3 Verify Spindle Function	76
4.6.4 Power off the Machine	77
4.7 Install Accessory Components	78
4.7.1 Set Up the Automatic Oiler	78
Specify the Interval Time	78
Specify the Actuation Time	78
4.7.2 Install the Automatic Tool Changer (ATC)	78
Required Tools	79
Required Tools for Installation	79
Required Tools for Verification	79
Air Requirements	79
Mount the Automatic Tool Changer (ATC) Bracket	79
Install the Main Assembly	80
Install the Air Cylinder	80
Make Air Connections	81

TABLE OF CONTENTS

<i>Make Electrical Connections</i>	81
<i>Verify the Installation</i>	81
<i>Level the Automatic Tool Changer (ATC)</i>	82
Prepare the Machine.....	83
Examine Perpendicularity in the Y Direction.....	83
Examine Perpendicularity in the X Direction.....	83
Examine the Alignment of the Carousel Door Opening.....	84
<i>Alignment</i>	85
4.7.3 Install the Flood Coolant Kit.....	87
<i>Adjust the Coolant Pump Motor Strapping</i>	87
<i>Set Up the Flood Coolant Kit</i>	87
4.7.4 Install the 4th Axis.....	88
<i>Set Up the microARC 4</i>	88
Required Tools.....	89
Install in Machine.....	89
Center the Chuck Mounting Plate.....	90
<i>Verify the Installation</i>	90
4.7.5 Install the Probe and Tool Setter.....	91
<i>Before You Begin</i>	91
Required Tools.....	91
Notes.....	91
<i>Wireless Receiver Installation</i>	91
<i>Tool Setter Installation and Setup</i>	93
Align the Tool Setter's Stylus.....	93
Reference the Tool Setter.....	94
Set G37 Position.....	95
<i>Wireless Probe Installation and Setup</i>	95
Adjust Probe Tip Concentricity.....	96
Set Probe Length and Diameter.....	96
Probe Status Lights Reference.....	98
4.8 Set Up the PathPilot Controller	99
4.8.1 Specify the Date and Time.....	99
4.8.2 Specify the Keyboard Language.....	99
4.8.3 Configure the Optional Touch Screen Kit.....	99
4.8.4 Update PathPilot.....	99
SYSTEM BASICS	101
5.1 System Reference	102
5.1.1 Machine Table.....	102
5.1.2 Spindle.....	102
<i>About the Spindle</i>	102
5.1.3 Axes.....	102
5.2 Basic Controls Reference	103
5.2.1 Machine Controls.....	103
5.2.2 PathPilot Interface.....	103

PATHPILOT INTERFACE OVERVIEW.....	105
6.1 About PathPilot	106
6.2 Notebook Section	107
6.2.1 Main Tab	107
6.2.2 File Tab	107
6.2.3 Settings Tab	108
6.2.4 Offsets Tab	108
6.2.5 Conversational Tab	108
6.2.6 Probe/ETS Tab	108
6.2.7 Status Tab	109
6.3 Persistent Controls	110
6.3.1 Program Control Area	110
6.3.2 Position Status Area	110
6.3.3 Manual Control Area	111
6.4 Keyboard Shortcuts	112
6.5 Manage PathPilot Versions	113
6.5.1 Download and Install an Update File from the Controller	113
6.5.2 Install an Update File from a USB Drive	113
6.5.3 Install a Previous Version of an Update File	114
PATHPILOT TOOLS AND FEATURES	115
7.1 Create and Load G-Code Files	116
7.1.1 Load G-Code	116
<i>Transfer Files to and From the Controller</i>	<i>116</i>
<i>Preview G-Code Files</i>	<i>116</i>
<i>Access Recent G-Code Files</i>	<i>117</i>
<i>Close the Current Program</i>	<i>117</i>
7.1.2 Edit G-Code	117
<i>Edit G-Code with a Text Editor</i>	<i>117</i>
<i>Edit G-Code with Conversational Programming</i>	<i>117</i>
Change the Step Order	118
Create a New Job Assignment	118
Load an Existing G-Code File	118
Edit a Job Assignment	118
7.1.3 Read G-Code	118
<i>Expand the G-Code Tab</i>	<i>118</i>
About the G-Code Tab	118
<i>Search in the Code</i>	<i>119</i>
<i>Set a New Start Line</i>	<i>119</i>
Lead-In Moves	120
<i>Change the View of the Tool Path Display</i>	<i>120</i>
About the Tool Path Display	121
7.1.4 Use Conversational Programming	121
<i>About Conversational Programming</i>	<i>121</i>

TABLE OF CONTENTS

- Create a Face on a Part 121
 - About Facing 122
 - Facing in PathPilot 122
 - Facing Reference 123
- Create a Profile on a Part 123
 - About Profiling 123
 - Profiling in PathPilot 123
 - Profiling Reference 124
- Create a Pocket on a Part 124
 - About Pockets 125
 - Creating Pockets in PathPilot 125
 - About Circular Pockets 125
 - About Rectangular Pockets 126
- Create Hole Locations on a Part (Drill/Tap) 126
 - About Drilling and Tapping 127
 - Drilling and Tapping in PathPilot 127
 - Create a Drilling Sequence 127
 - Create a Tapping Sequence 128
 - Drilling and Tapping Reference 128
- Create Threads on a Part 129
 - About Thread Milling 129
 - Thread Milling in PathPilot 129
 - Thread Milling Reference 130
- Create Text to Engrave on a Part 130
 - About Engraving 131
- Import a DXF File 131
 - Working with Layers and Shapes 131
 - Change the Layer or Shape Cut Order 131
 - Adjust the Tree View Window 132
 - Working in the Preview Window 132
- 7.2 Machine Settings and Accessories 133**
 - 7.2.1 Enable an Internet Connection 133
 - Enable Automatic Updates 133
 - 7.2.2 Change the Network Name 134
 - 7.2.3 Select the Spindle Type 134
 - 7.2.4 Change the Screen Orientation 134
 - About Portrait Screen Layout 135
 - 7.2.5 Specify the Tool Change Method 136
 - About Automatic Tool Changes 136
 - About Manual Tool Changes 136
 - 7.2.6 Disable Hard Stop Referencing 136
 - About Limit Switches 137
 - 7.2.7 Limit G30 Moves 137
 - About G30 137
 - 7.2.8 Enable the On-Screen Keyboard 137

<i>About Soft Keyboards</i>	137
7.2.9 Enable the USB M-Code I/O Interface Kit	138
7.2.10 Enable Tooltips.....	138
7.2.11 Enable the Door Lock Switch Kit	138
7.2.12 Enable Feeds and Speeds Suggestions in Conversational Routines.....	139
7.2.13 Specify Probing and Tool Measuring Options.....	139
7.2.14 Use the RapidTurn Interface.....	139
7.2.15 Specify the 4th Axis Rotary Type.....	139
<i>Enable the 4th Axis Homing Kit</i>	139
7.2.16 Use a USB Camera.....	140
<i>About USB Cameras</i>	140
<i>Manual Recording</i>	140
<i>Automatic E-Stop Loop Recording ("Dashcam")</i>	141
<i>Review Video and Image Files</i>	141
File Naming Convention.....	142
<i>G-Code Commands</i>	142
File Naming Conventions.....	142
Use M01 to Take Pictures.....	142
7.3 Set Up G-Code Programs	143
7.3.1 Use a Probe with PathPilot.....	143
<i>Set Up the Probe</i>	143
<i>Use a Probe to Find a Feature's Location</i>	143
<i>Use a Probe to Set Work Offset Zeroes</i>	143
Set the X and Y Work Offset Zero on the Corner of a Feature.....	143
Set the Work Offset Zeroes on a Feature.....	143
<i>Use a Probe to Find the Center of a Feature</i>	144
Find the Center of a Pocket.....	144
Find the Center of a Slot.....	144
Find the Center of a Rectangular Boss.....	144
Find the Center of a Circular Boss.....	144
Find the Center Rotation of an A-Axis.....	145
7.3.2 Set Tool Length Offsets.....	145
<i>About Tool Offsets</i>	145
<i>Touch Off the Tool Length Offsets</i>	146
Set a Known Reference Height.....	146
Measure Tools Using a Known Reference Height.....	146
<i>Use an Electronic Tool Setter (ETS) to Measure Tools</i>	147
<i>Use a Tool Height Setter to Measure Tools</i>	147
Set a Known Reference Height.....	147
Verify the Calibration of the Tool Height Setter.....	148
7.3.3 Set Work Offsets.....	148
<i>About Work Offsets</i>	149
7.3.4 View Work Offsets.....	149
7.3.5 View Available G-Code Modes.....	149
7.4 Run G-Code Programs	150

TABLE OF CONTENTS

- 7.4.1 Bring the Machine Out of Reset 150
 - About Reset Mode 150
- 7.4.2 View the Active Axis to Jog 150
- 7.4.3 Jog the Machine 150
 - Jog in Continuous Velocity Mode 151
 - About Continuous Velocity Jogging 151
 - Jog in Step Mode 151
 - About Step Jogging 151
- 7.4.4 View the Current Machine Position 151
- 7.4.5 Reference the Machine 152
 - About Referencing 152
- 7.4.6 Start a Program 152
 - About Cycle Start 152
 - Cycle Start Reference 152
- 7.4.7 Stop Machine Motion 153
- 7.4.8 Operate the Coolant Pump 153
 - About Coolant 153
- 7.4.9 View the Active G-Code Modes 153
- 7.4.10 View the Distance to Go 153
 - About Distance to Go 153
- 7.5 Control G-Code Programs 154**
 - 7.5.1 Use the Feed Hold Function 154
 - About Feed Hold 154
 - 7.5.2 Use the Feed Rate Override Function 154
 - About Feed Rate Override 154
 - 7.5.3 Use M01 Break Mode 155
 - About M01 Break 155
 - Display Information and Capture Images During an M00 or M01 Break 155
 - Display Information with Images 155
 - Display Information with Text 155
 - Capture Images with a USB Camera 155
 - 7.5.4 Use the Maxvel Override Function 155
 - About Maxvel Override 156
 - 7.5.5 Use Single Block Mode 156
 - About Single Block 156
 - 7.5.6 Use the Spindle Override Function 156
 - About Spindle Override 156
 - 7.5.7 Change the Feed Rate 157
 - About Feed Rates 157
 - 7.5.8 Change the Spindle Speed 157
 - About Spindle Controls 157
 - 7.5.9 Change the Tool Number 157
 - About M6 G43 157
 - 7.5.10 Use a G30 Position 158
 - About G30 158

7.5.11 View the Tool Length	158
7.5.12 Manually Enter Commands	158
<i>About the MDI Line DRO Field.</i>	158
<i>Admin Commands Reference.</i>	159
7.5.13 Copy Recently Entered Commands	159
7.5.14 Use Feeds and Speeds Suggestions	160
<i>Refresh DRO Field Values.</i>	160
<i>Use Additional Provided Information.</i>	161
<i>Create Tool Descriptions.</i>	161
Manually Enter Tool Descriptions	161
Automatically Generate Tool Descriptions	162
<i>Tool Keywords Reference.</i>	162
7.5.15 Use Cycle Counters (M30 and M99)	163
<i>Monitor Cycle Counters.</i>	163
<i>Change Cycle Counter Values.</i>	163
7.6 System File Management	164
7.6.1 Manage System Files	164
7.6.2 Create Backup Files	164
<i>About Backup Files.</i>	165
7.6.3 Restore Backup Files	165
7.6.4 Import and Export the Tool Table	166
<i>Import a .csv File.</i>	166
<i>Export the Tool Table as a .csv File.</i>	166
BASIC OPERATIONS	167
8.1 Start the Machine	168
8.2 Bring the Machine Out of Reset	169
8.2.1 About Reset Mode	169
8.3 Reference the Machine	170
8.3.1 About Referencing	170
8.4 Jog the Machine	171
8.4.1 About Jogging	171
<i>About Continuous Velocity Jogging.</i>	171
<i>About Step Jogging.</i>	171
8.4.2 Jog Controls Reference	172
<i>Jogging in PathPilot.</i>	172
<i>Jogging with the Keyboard.</i>	172
<i>Jogging with the (Optional) Jog Shuttle or Operator Console Pendant.</i>	172
8.5 Manually Control the Spindle	173
8.5.1 About the Spindle	173
8.6 Load G-Code	174
8.6.1 Transfer Files to and From the Controller	174
8.7 Set Up Tooling	175
8.7.1 Install a Tool in a Set Screw Tool Holder	175
8.7.2 Install a Tool in an ER Collet Tool Holder	175

TABLE OF CONTENTS

8.7.3 Install a Drill Chuck in a Jacobs Taper Arbor.....	175
8.8 Set Tool Length Offsets.....	176
8.8.1 About Tool Offsets.....	176
8.8.2 Touch Off the Tool Length Offsets.....	176
<i>Set a Known Reference Height.....</i>	<i>176</i>
<i>Measure Tools Using a Known Reference Height.....</i>	<i>177</i>
8.8.3 Use an Electronic Tool Setter (ETS) to Measure Tools.....	178
8.8.4 Use a Tool Height Setter to Measure Tools.....	178
<i>Set a Known Reference Height.....</i>	<i>178</i>
<i>Verify the Calibration of the Tool Height Setter.....</i>	<i>179</i>
8.9 Set Work Offsets.....	180
8.9.1 About Work Offsets.....	180
8.10 Operate the Coolant Pump.....	181
8.10.1 About Coolant.....	181
PROGRAMMING.....	183
9.1 Programming Overview.....	184
9.1.1 About G-Code Programming Language.....	184
9.1.2 G-Code Formatting Reference.....	184
<i>Line Numbers.....</i>	<i>184</i>
<i>Words.....</i>	<i>184</i>
<i>Letters.....</i>	<i>185</i>
<i>Values.....</i>	<i>185</i>
<i>Order of Execution.....</i>	<i>186</i>
<i>Modal Groups.....</i>	<i>187</i>
<i>Comments.....</i>	<i>188</i>
9.1.3 Supported G-Codes Reference.....	188
9.2 Programming G-Code.....	190
9.2.1 About the Examples Used.....	190
9.2.2 Rapid Linear Motion (G00).....	190
9.2.3 Linear Motion at Feed Rate (G01).....	190
9.2.4 Arc at Feed Rate (G02 and G03).....	191
<i>Radius Format Arc.....</i>	<i>191</i>
<i>Center Format Arc.....</i>	<i>191</i>
Arc in XY Plane.....	192
Arc in XZ Plane.....	192
Arc in YZ Plane.....	192
9.2.5 Dwell (G04).....	193
9.2.6 Set Offsets (G10).....	193
<i>Set Tool Table (G10 L1).....</i>	<i>193</i>
<i>Set Coordinate System (G10 L2).....</i>	<i>193</i>
<i>Set Tool Table (G10 L10).....</i>	<i>193</i>
<i>Set Tool Table (G10 L11).....</i>	<i>194</i>
<i>Set Coordinate System (G10 L20).....</i>	<i>194</i>
9.2.7 Plane Selection (G17, G18, G19).....	194

9.2.8 Length Units (G20 and G21).....	194
9.2.9 Return to Predefined Position (G28 and G28.1).....	194
9.2.10 Return to Predefined Position (G30 and G30.1).....	195
9.2.11 Automatically Measure Tool Lengths with an ETS (G37 and G37.1).....	195
<i>Move to G37 Position Over ETS (G37.1).....</i>	195
<i>Move and Measure Tool Length (G37).....</i>	195
9.2.12 Straight Probe (G38.x).....	196
<i>Use the Straight Probe Command.....</i>	196
9.2.13 Cutter Compensation (G40, G41, G42).....	197
9.2.14 Dynamic Cutter Compensation (G41.1 and G42.1).....	197
9.2.15 Apply Tool Length Offset (G43).....	198
9.2.16 Engrave Sequential Serial Number (G47).....	198
9.2.17 Cancel Tool Length Compensation (G49).....	198
9.2.18 Absolute Coordinates (G53).....	198
9.2.19 Select Work Offset Coordinate System (G54 to G54.1 P500).....	199
9.2.20 Set Exact Path Control Mode (G61).....	199
9.2.21 Set Blended Path Control Mode (G64).....	199
9.2.22 Distance Mode (G90 and G91).....	199
9.2.23 Arc Distance Mode (G90.1 and G91.1).....	199
9.2.24 Temporary Work Offsets (G92, G92.1, G92.2, and G92.3).....	199
9.2.25 Feed Rate Mode (G93, G94, and G95).....	200
9.2.26 Spindle Control Mode (G96 and G97).....	200
9.3 Programming Canned Cycles.....	202
9.3.1 Canned Cycles Reference.....	202
<i>Supported Canned Cycles.....</i>	202
9.3.2 High Speed Peck Drill (G73).....	203
9.3.3 Cancel Canned Cycles (G80).....	203
9.3.4 Drilling Cycle (G81).....	203
9.3.5 Simple Drilling Cycle (G82).....	205
9.3.6 Peck Drilling Cycle (G83).....	205
9.3.7 Tapping Cycle (G84).....	205
9.3.8 Boring Cycle (G85).....	205
9.3.9 Boring Cycle (G86).....	206
9.3.10 Boring Cycle (G88).....	206
9.3.11 Boring Cycle (G89).....	206
9.4 Programming M-Code.....	207
9.4.1 Supported M-Codes Reference.....	207
9.4.2 Program Stop and Program End (M00, M01, M02, and M30).....	207
<i>Display Information and Capture Images During an M00 or M01 Break.....</i>	208
Display Information with Images.....	208
Display Information with Text.....	208
Capture Images with a USB Camera.....	208
9.4.3 Spindle Control (M03, M04, and M05).....	208
9.4.4 Tool Change (M06).....	208
9.4.5 Coolant Control (M07, M08, and M09).....	209

TABLE OF CONTENTS

9.4.6 Override Control (M48 and M49).....	209
9.4.7 Feed Override Control (M50).....	209
9.4.8 Spindle Speed Override Control (M51).....	209
9.4.9 Set Current Tool Number (M61).....	209
9.4.10 Set Output State (M64 and M65).....	209
9.4.11 Wait on Input (M66).....	210
9.4.12 Switched Outlet Control (M264 and M265).....	210
9.4.13 USB Camera Control (M301, M302, M303).....	210
9.5 Programming Input Codes.....	211
9.5.1 Feed Rate (F).....	211
9.5.2 Spindle Speed (S).....	211
9.5.3 Change Tool Number (T).....	211
9.6 Advanced Programming.....	212
9.6.1 Parameters.....	212
<i>Parameters Reference.....</i>	<i>212</i>
Parameter Syntax.....	212
Parameter Scope.....	212
Behavior of Uninitialized Parameters.....	212
Parameter Mode.....	212
Persistence and Volatility.....	212
Intended Use.....	212
<i>Numbered Parameters Reference.....</i>	<i>213</i>
Read-Only Parameters.....	213
<i>Subroutine Parameters Reference.....</i>	<i>213</i>
<i>Named Parameters Reference.....</i>	<i>213</i>
9.6.2 Expressions.....	214
<i>Binary Operators Reference.....</i>	<i>214</i>
<i>Functions Reference.....</i>	<i>214</i>
9.6.3 Subroutines.....	215
<i>Subroutines Reference.....</i>	<i>215</i>
<i>Conditional Subroutines Reference.....</i>	<i>216</i>
if/endif.....	216
if/elseif/else/endif.....	216
<i>Repeating Subroutines Reference.....</i>	<i>216</i>
<i>Looping Subroutines Reference.....</i>	<i>216</i>
do/while.....	217
while/endwhile.....	217
MACHINE MAINTENANCE.....	219
10.1 Maintenance Safety.....	220
10.1.1 All Maintenance Procedures.....	220
10.1.2 Swarf Maintenance Procedures.....	220
10.1.3 Coolant Maintenance Procedures.....	220
10.2 Maintenance Schedules.....	221
10.2.1 Daily.....	221

10.2.2 Weekly.....	221
10.2.3 Monthly.....	221
10.2.4 Semi-Annually.....	221
10.2.5 Annually.....	221
10.3 Regular Maintenance.....	222
10.3.1 Clean the Way Covers.....	222
10.3.2 Clean the Coolant System.....	222
<i>About Cutting Fluid.....</i>	222
<i>Cutting Fluid Reference.....</i>	222
10.3.3 Examine the Drawbar.....	223
10.3.4 Examine the Enclosure Windows.....	223
10.3.5 Lubricate the Machine.....	223
<i>About the Manual Oiler.....</i>	223
<i>About the Automatic Oiler.....</i>	223
<i>Lubrication System Reference.....</i>	223
10.3.6 Examine the Spindle Belt.....	224
10.3.7 Examine the Pull Stud Clamp.....	224
10.3.8 Prevent Rust.....	224
<i>Remove Rust.....</i>	224
DIAGRAMS AND PARTS LISTS.....	225
11.1 Mill Assembly.....	226
11.2 X-Axis Assembly.....	228
11.3 Y-Axis Assembly.....	231
11.4 Y-Axis Saddle Subassembly.....	233
11.5 Z-Axis Assembly.....	235
11.6 Enclosure Assembly.....	238
11.6.1 Enclosure Door Assembly.....	241
ELECTRICAL SCHEMATICS.....	245
12.1 240 Vac Power (Page 1).....	246
12.2 24 Vdc/75 Vdc Power (Page 2).....	247
12.3 Breakout Board - Digital Inputs and Outputs (Page 3).....	248
12.4 Breakout Board - Power, Drives, Aux Outputs, and Safety (Page 4).....	249
12.5 Breakout Board - Aux Inputs, Brakes, and Vac Control (Page 5).....	250
12.6 Spindle Drive (Page 6).....	251
12.7 XYZ Axis Drives (Page 7).....	252
12.8 A-Axis Stepper Drive (microARC 4) (Page 8).....	253
12.9 A-Axis Servo Drive (microARC 6) (Page 9).....	254
12.10 Accessory/Aux (Page 10).....	255
12.11 Operator Panel (Page 11).....	256
12.12 Enclosure (Page 12).....	257
12.13 Power Drawbar (Page 13).....	258
12.14 Grounds (Page 14).....	259
12.15 Terminal Strip - AC (X1) (Pages 15-16).....	260

TABLE OF CONTENTS

12.16 Terminal Strip- Drive Power (X2) (Pages 17-18).....262

12.17 Terminal Strip - DC (X3) (Page 19).....264

12.18 Terminal Strip - Grounds (X4) (Page 20)..... 265

12.19 Bill of Materials (Pages 21-22)..... 266

SAFETY

IN THIS SECTION, YOU'LL LEARN:

- About the standards and safety precautions associated with this machine.



Before operating the machine in any way, you must read and understand this section.

Safe operation of the machine depends on its proper use and the precautions you take. Only trained personnel — with a clear and thorough understanding of its operation and safety requirements — shall operate this machine.

CONTENTS

1.1 Intended Use	20
1.2 Machine Standards	21
1.3 Safety Overview	22
1.4 Machine Safety	25
1.5 Noise Exposure	28

1: SAFETY

1.1 Intended Use

1.1 INTENDED USE

This machine is intended for general-purpose, computer numerical control (CNC) machining in the following applications:

- Educational environments
- Hobby applications
- Light production
- Prototyping
- Research and development
- Secondary operations

The intended use includes:

- Appropriate workholding, toolholding, tooling, coolant systems, and machining parameters.
- Machining of conventional, non-abrasive materials such as ferrous and non-ferrous metals below 60 HRC, woods, and plastics.

The intended use **does not** include machining materials that:

- Are abrasive, carcinogenic, explosive, flammable, radioactive, or toxic
- Produce aerosols or fine particulates when machined

The intended use **does not** include the following materials (not a full list):

- Beryllium and its alloys
- Ceramics
- Fiberglass
- G10 fiberglass laminate
- Graphite
- Magnesium and its alloys

To safely operate products, you must obey all safety precautions and warnings that are on the machines and in the documentation.

1.2 MACHINE STANDARDS

When installed and operated as intended (see "Intended Use" (on the previous page)), this machine complies with the following standards. You must follow the requirements listed in the standards so that the machine remains compliant.

1.2.1 American National Safety Institute (ANSI)

- **ANSI B11.TR3-2000** *Risk Assessment and Risk Reduction — A Guideline to Estimate, Evaluate, and Reduce Risks Associated with Machine Tools*
- **ANSI B11.8-2001** *Safety Requirements for Manual Milling, Drilling, and Boring Machines with or without Automatic Control*
- **ANSI B11.19-2010** *Performance Requirements for Safeguarding*
- **ANSI B11.23-2002** *Safety Requirements for Machining Centers and Automatic Numerically Controlled Milling, Drilling, and Boring Machines*

1.2.2 Occupational Safety and Health Administration (OSHA)

- **OSHA 1910.212** *General Requirements for All Machines*
- **OSHA 3067** *Concepts and Techniques of Machine Safeguarding*

1: SAFETY

1.3 Safety Overview

1.3 SAFETY OVERVIEW

Any machine tool is potentially dangerous. A CNC machine's automation presents added risk not present in a manual machine.

Before operating the machine in any way, you must read and understand this section.

- Read and understand all safety messages used in this document.
- Locate and understand all safety decals on the machine.
- Locate and become familiar with all information decals on the machine.

1.3.1 Safety Messages

The following examples show the standard safety message types used to draw your attention to important information. The standards distinguish between personal injury safety messages and property damage warning messages.

Personal Injury

Personal injury safety messages have safety alert symbols and the following hazard level labels:

⚠ DANGER! Indicates a hazard with a high level of risk which, if not avoided, will result in death or serious injury.

⚠ WARNING! Indicates a hazard with a medium level of risk which, if not avoided, can result in death or serious injury.

⚠ CAUTION! Indicates a hazard with a low level of risk which, if not avoided, can result in minor or moderate injury.

Property Damage

📌 NOTICE! Indicates a hazard which, if not avoided, can cause property damage.

1.3.2 Safety Decals

Before operating the machine in any way, you must read and

understand all installed safety decals on the machine and equipment. Do not remove any safety decals. If any safety decals become worn or damaged, contact Tormach Technical Support for guidance on receiving replacement decals.

The following types of safety symbols are on the decals:

- **Warning** ⚠ This symbol indicates a hazard which, if not avoided, can result in personal injury or property damage.
- **Prohibition** 🚫 This symbol indicates an action that shall not be taken or that shall be stopped.
- **Mandatory Action** 🛑 This symbol indicates an action that you must take to avoid a hazard.

On the Electrical Cabinet Door

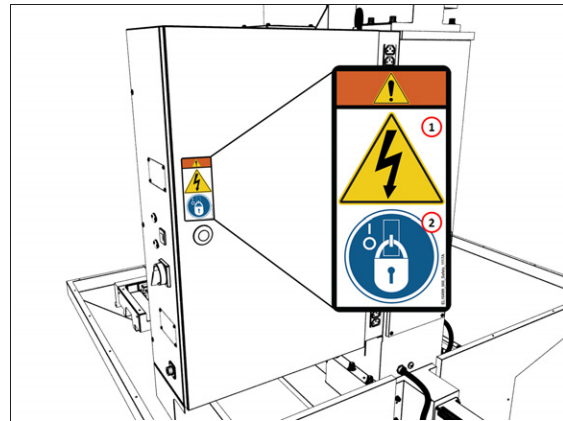


Figure 1-1: Example of a safety decal on the electrical cabinet door.

1. **WARNING! Electrocuting Hazard.** Points in the electrical cabinet contain high voltages, which can electrocute or shock you, causing death or serious injury. Even after the machine is powered off, electronic devices in the electrical cabinet can retain dangerous electrical voltages. Use caution when servicing the machine inside the electrical cabinet.
2. **Lockout/Tagout.** Before servicing the machine, you must power off the machine and use an approved lockout/tagout device to secure the Main Disconnect switch in the **OFF** position. Points in the electrical cabinet contain high voltages, which can electrocute or shock you, causing death or serious injury.

Next to the Main Disconnect

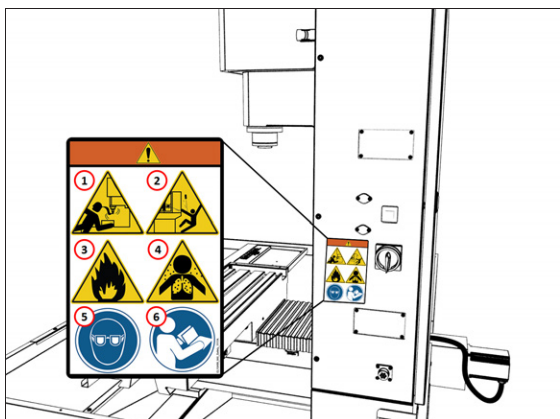


Figure 1-2: Example of a safety decal next to the Main Disconnect.

1. **WARNING! Entanglement / Entrapment Hazard.** The machine operates under automatic control — it can start at any time and crush, cut, entangle, or pinch body parts. Always keep clear of positions on the machine where unexpected or unintended machine motion could cause harm. Before operating this machine in any way, you must verify that all operators know the location of the machine's Emergency Stop button.
2. **WARNING! Ejection Hazard.** Fixtures, tooling, workpieces, or other loose items can become dangerous projectiles and can cause death or serious injury. Before operating this machine in any way, you must verify that you have appropriately secured all components.
3. **WARNING! Fire Hazard.** The machine and its enclosure are not designed to contain fire or explosions. Only use materials and coolants that are intended for the specific machining operation. Never use flammable or explosive items. Before operating the machine in any way, you must read all Safety Data Sheets (SDSs) for any workpiece materials, coatings, coolants, lubricants, and other consumables used.
4. **WARNING! Inhalation Hazard.** The machine and its enclosure do not protect you from airborne particulates. Chips, dust, and vapors from certain materials can be toxic or otherwise harmful. Before operating the machine in any way, you must read all Safety Data Sheets (SDSs) for any workpiece materials, coatings, coolants, lubricants, and other consumables used.
5. **Personal Protective Equipment: Eyes.** Prevent injury by

always wearing protective safety eyewear. Before operating this machine in any way, you must verify that your eyewear is impact-resistant and rated for ANSI Z87+.

6. **Operator Knowledge.** Before operating this machine in any way, you and all other operators must read and understand all instructions. If you don't, there's a risk of voided warranty, property damage, serious injury, or death.

On the Spindle Nose

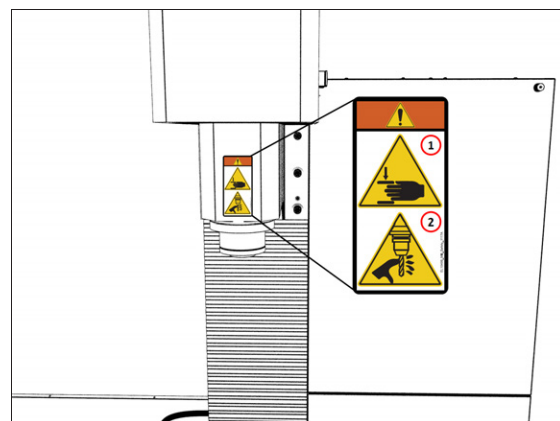


Figure 1-3: Example of a safety decal on the spindle nose.

1. **WARNING! Crush Hazard.** Moving parts can entangle, pinch, or cut you, causing death or serious injury. Before operating this machine in any way, you must verify that all body parts, long hair, and clothes are clear of the machine's extent of motion.
2. **WARNING! Cut Hazard.** Tools and swarf can cut you. Only hold tools by the tool holder. Before inserting or removing tools from the machine, you must verify that all motion is completely stopped.

1.3.3 Information Decals

Before operating the machine in any way, you must locate and become familiar with all installed information decals on the machine and equipment.

Serial Number Plate

The serial number plate is on the side of the electrical cabinet, near the Main Disconnect switch.

1: SAFETY

1.3 Safety Overview

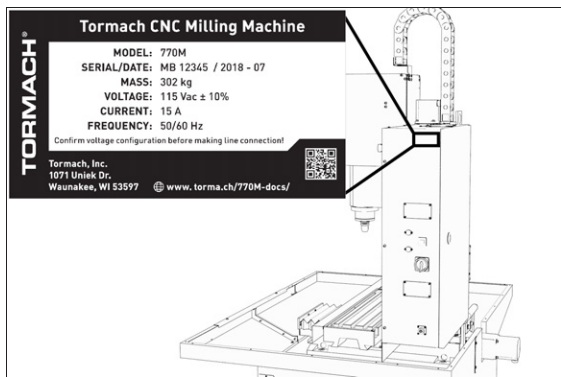


Figure 1-4: Example of the serial number plate on the side of the electrical cabinet.

1.4 MACHINE SAFETY



Before operating the machine in any way, you must read and understand this section.

Safe operation of the machine depends on its proper use and the precautions you take. Only trained personnel — with a clear and thorough understanding of its operation and safety requirements — shall operate this machine.

1.4.1 General Shop Safety	25
1.4.2 Operational Safety	25
1.4.3 Electrical Safety	26

1.4.1 General Shop Safety

- ✓ Verify that only qualified machinery maintenance professionals install, set up, or perform maintenance on this machine.
- ✓ Keep the work area well-lit. Use additional lighting if needed. The work area should be illuminated to a minimum of 500 lx.
- ✓ Keep the work area temperature- and humidity-controlled.
- ✓ Remove loose-fitting clothing, neckties, gloves, and jewelry.
- ✓ Tie up long hair and secure it under a hat.
- ✓ Wear safety eye protection rated for ANSI Z87+.
- ✓ Wear closed-toed safety shoes.
- ✓ Wear ear protection when you expect the machine or the machining processes to exceed safe exposure limits. For information, see "Noise Exposure" (page 28).
- ✓ Keep the work area clean and free of clutter. Machine motion can occur if controls are accidentally activated.
- ✓ Immediately clean up spills after they occur.
- ✗ Never operate the machine after consuming alcohol or taking medication that could prevent you from safely operating the machine.
- ✗ Never operate the machine while tired or otherwise impaired.
- ✗ Never operate the machine in an explosive (ATEX) atmosphere. Such explosive atmospheres include explosive gases, vapors, mists, powders, and dusts.

1.4.2 Operational Safety

General

- ✓ Understand that the machine is automatically controlled and can start at any time.
- ✓ If anyone enters the machining envelope during operation, immediately push in the Emergency Stop button. In case of a power loss, turn the Door Switch Override to the Unlocked position and open the enclosure doors.
- ✓ Become familiar with all physical and software controls.
- ✓ Always use a chip scraper or brush when clearing away chips, oil, or coolant.
- ✓ Examine all tools, fixtures, workpieces, and guarding for signs of damage. Replace any damaged components as soon as you find them.
The enclosure and other guards may not stop all types of projectiles, like broken tools or loose workpieces.
- ✓ Stop the machine and verify that all machine motion has completely stopped before doing any of the following:
 - ✓ Adjusting a part, fixture, or coolant nozzle.
 - ✓ Changing belt or pulley positions.
 - ✓ Changing tools or parts.
 - ✓ Clearing away chips, oil, or coolant.
 - ✓ Reaching into any part of the machine's motion envelope.
 - ✓ Removing protective shields or safeguards.
 - ✓ Taking measurements.
 - ✓ Doing any other action inside the machine enclosure.
- ✓ Use flood or MQL (mist) coolant as required by the machining operation.
- ✓ Only use coolants designed for metal working applications such as soluble oils, semi-synthetic, or synthetic coolants.
- ✓ Read the Safety Data Sheet (SDS) for all workpiece materials, coatings, coolants (flood or MQL), lubricants, and other consumables. Chips, dust, and vapors from certain materials can be toxic or otherwise harmful.
- ✓ Understand that this product can expose you to chemicals which are known to the State of California to cause cancer and birth defects or other reproductive harm. For more information, go to www.P65Warnings.ca.gov.

1: SAFETY

1.4 Machine Safety

- ✓ Dispose of scrap and swarf according to local regulations and guidelines.
- ✓ Thoroughly read all safety precautions and instructions.
- ✓ When machining an unproven program, use feed, speed, and maximum velocity overrides, Distance-to-Go (DTG) displays, single block, feed hold, and other control features.
- ✓ Follow all appropriate "Machine Standards" (page 21).
- ✗ Never enter the machining envelope.
- ✗ Never reach around a guard.
- ✗ Never allow the machine to run unattended.
- ✗ Never obstruct the Emergency Stop button or any other controls.
- ✗ Never allow untrained operators to install, operate, or maintain the machine.
- ✗ Never modify, defeat, or bypass safety devices or interlocks.
- ✗ Never machine abrasive, carcinogenic, explosive, flammable, radioactive, or toxic materials. Such materials include, but are not limited to:
 - ✗ Beryllium and its alloys
 - ✗ Ceramic
 - ✗ Fiberglass
 - ✗ G10 fiberglass laminate
 - ✗ Graphite
 - ✗ Lead and its alloys
 - ✗ Magnesium and its alloys
- ✗ Never allow swarf to accumulate on or within the machine.
- ✗ Never use flammable liquids (like alcohol, diesel fuel, or kerosene) in the machine's coolant system.
- ✗ Never use water, coolants without rust inhibitors, or straight cutting oil in the machine's coolant system.

Tooling

- ✓ Use appropriate speeds, feeds, and cutting parameters for your machine, machine operation, material, and tooling.
- ✓ Use tools and tool holders that are suitable for the current operation.
- ✓ Examine tools for signs of damage. Replace any damaged tools as soon as you find them.

- ✓ The enclosure and other guards may not stop all types of projectiles, like broken tooling.
- ✗ Never use unbalanced tooling or spindle fixtures.
- ✗ Never use tools that are larger or longer than necessary.
- ✗ Never use tools at speeds above their operational limits.

Workholding

- ✓ Secure workpieces with appropriate workholding devices (like a milling vise or strap clamps).
- ✓ Verify that the workpiece is adequately secured.
- ✓ Position clamps and workholding devices clear of any tool paths.
- ✓ Remove cutoff workpieces and other large chips before starting the machine.
- ✗ Never leave tools, stock, or other loose items inside the machine.

1.4.3 Electrical Safety



WARNING! Electrical Shock Hazard: You must power off the machine before making any electrical connections. If you don't, there's a risk of electrocution or shock.

- ✓ Power off the machine before servicing.
- ✓ Use an approved lockout/tagout system to secure the machine's Main Disconnect in the **OFF** position before servicing the machine.
- ✓ Understand that certain electrical components can retain dangerous electrical voltages, even after the machine is powered off and all power is removed from the system.
- ✓ Understand that certain installation, maintenance, and troubleshooting procedures — for the machine and certain accessories — require access to or modification of wiring inside of the electrical cabinet. Only qualified electrical machinery technicians shall perform these procedures.
- ✓ Confirm that the mains voltage conforms to requirements before connecting the machine.
For more information, see "Electrical and Power Requirements" (page 36).
- ✓ Confirm that the machine installation meets all codes and regulations of your locality.

- ✓ Confirm that electrical connections are performed by a certified electrician.
- ✓ Lock the electrical cabinet door and remove the keys when the machine is not being serviced to prevent unqualified or unauthorized personnel from accessing the electrical cabinet.
- ✗ Never operate the machine with the electrical cabinet door open.
- ✗ Never reach into the electrical cabinet with the machine powered on.
- ✗ Never modify the machine's electronics.
- ✗ Never drill into the electrical cabinet.

1: SAFETY

1.5 Noise Exposure

1.5 NOISE EXPOSURE



CAUTION! Noise Exposure Hazard: If you expect the machine or the machining processes to exceed safe exposure limits, you must wear ear protection.

With the axes moving and the spindle rotating (but not cutting), the emission sound pressure level at the operator control station is 77 dB(A).

Emission sound pressure levels vary depending on the machining processes. Factors that influence the actual level of noise exposure may include:

- Characteristics of the work room
- Other sources of noise (like the number of machines, or other adjacent processes)

The permissible noise exposure level may vary between countries. You must evaluate of the hazard and risk based on your locality, and mitigate as necessary.

ABOUT YOUR MACHINE

IN THIS SECTION, YOU'LL LEARN:

- About this machine's specifications.

CONTENTS

2.1 Machine Specifications.....	30
---------------------------------	----

2: ABOUT YOUR MACHINE

2.1 Machine Specifications

2.1 MACHINE SPECIFICATIONS

Travels	
X-Axis	14" (356 mm)
Y-Axis	7.5" (191 mm)
Z-Axis	13.25" (337 mm)
Spindle-to-Table Maximum Clearance	13.75" (349 mm)
Spindle-to-Table Minimum Clearance	0.5" (13 mm)
Spindle Centerline to Machine Column	8.6" (218 mm)
Spindle	
Spindle Power	2 hp (1.5 kW)
Spindle Power Peak	4.5 hp (3.4 kW)
Spindle Maximum Speed	10,000 rpm
Transmission	5M Toothed Belt
Spindle Taper	BT30
Thread Machining	Rigid Tapping, Tension/Compression, Thread Mill
Maximum Feed Rate	
X- and Y-Axis	450 IPM (11.4 m/min)
Z-Axis	420 IPM (10.6 m/min)
Axis Motor	Servo Driven
Power and Air	
Primary Power Required*	Single-Phase 230 Vac, 50/60 Hz
Recommended Circuit Amperage*	Dedicated 20 A breaker
Plug Type	NEMA 6-20P
Air Required	90-120 psi Typical Draw [†] < 3.0 CFM (85 L/min)
Table	
Table Size	26" × 8" (660 mm × 203 mm)
T-Slot Size	5/8" (15.9 mm) (three slots)
T-Slot Spacing	2" (50 mm)
Maximum Weight on Table	500 lb (227 kg)
Overall Dimensions	
Machine Size [†]	56" × 49" (1.4 m × 1.2 m)

Overall System Height [†]	88" (2.2 m)
Typical System Weight [†]	950 lb (431 kg)
*Additional outlets may be required for optional accessories. [†]Installed size, weight, and air consumption depend on machine options and accessories. You may need additional space for service or maintenance access. Refer to "Site Requirements" (on page 1) for additional details. Solid models for space planning are available <u>at tormach.com/support/mill/770mx-solid-models-and-drawings</u>.	



FORMACH

700

SITE REQUIREMENTS

IN THIS SECTION, YOU'LL LEARN:

- About the site requirements of this machine (including electrical and power requirements).



Before operating the machine in any way, you must read and understand this section.

CONTENTS

3.1 General Site and Space Requirements	34
3.2 Electrical and Power Requirements	36
3.3 Air Requirements	37
3.4 Space Planning Drawings	38



TORMACH®

3: SITE REQUIREMENTS

3.1 General Site and Space Requirements

3.1 GENERAL SITE AND SPACE REQUIREMENTS

When choosing a location for your machine, you must verify that it meets all requirements outlined in this section.

3.1.1 Site Requirements

You must verify that the area:

- Allows for unrestricted access to machine controls.
- Conforms to the following:
 - **Primary Power Required** Single-Phase 230 Vac, 50/60 Hz
 - **Recommended Circuit Amperage** Dedicated 20 A breaker



Note: For more information, see "Electrical and Power Requirements" (page 36).

- Has clean, dry, compressed air.
- Has one continuous slab sufficient to support the weight of the machine, accessories, and any additional equipment.
- Is a dry, properly ventilated, and well-lit internal space that conforms to the following temperature and humidity requirements:
 - **Operating Temperature Range** 40°F-100°F (5°C-38°C)
 - **Humidity Range** 5%-95% (non-condensing)
- Provides for unobstructed machine motion and operation.

3.1.2 Space Requirements

The area must meet the following space requirements. Allow more space to access the rear of the machine for maintenance and repairs.



Note: For a detailed drawing of the space requirements, refer to the end of this chapter.

- **Machine Size** 56" × 49" (1.4 m × 1.2 m)
- **Machine Height** 88" (2.2 m)

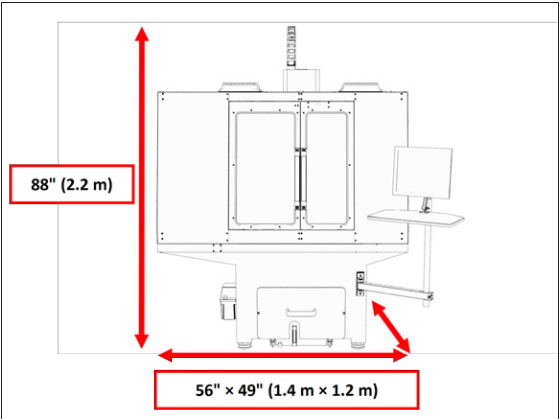


Figure 3-1: Dimensions of the machine itself, as viewed from the front.

- **Typical System Footprint** 76" × 63" (1.9 m × 1.6 m)

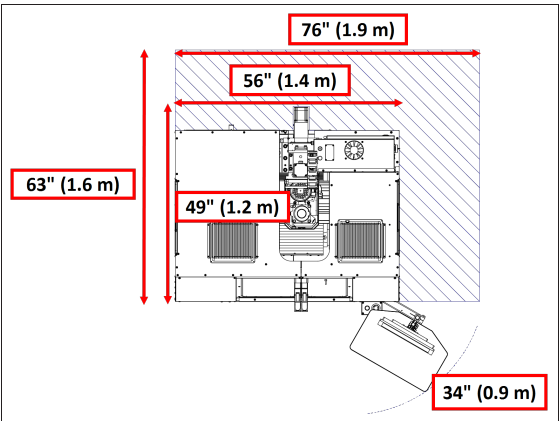


Figure 3-2: Dimensions of the machine and its required added space, as viewed from above.

If a pallet is too wide to fit through a doorway, see [Moving Dimensions](#). Or, if you have the optional [Moving Kit \(PN 31333\)](#), see the documentation included with the product.

3.1.3 Operator Workstation Reference

The typical operator workstation is the area in front of the enclosure doors and the PathPilot controller, as shown in the following image.

3: SITE REQUIREMENTS

3.1 General Site and Space Requirements

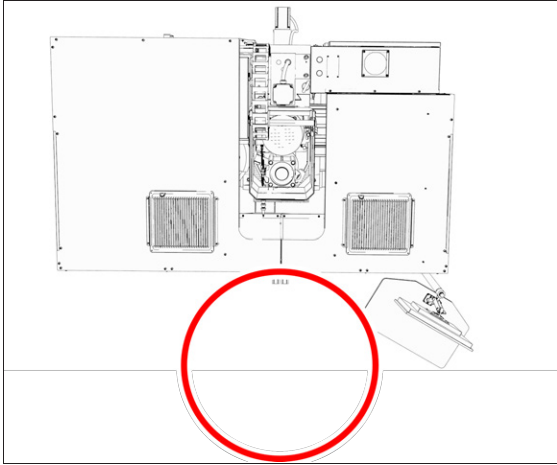


Figure 3-3: Example of the typical operator workstation.

For information on the machine controls, go to "System Basics" (page 101).

3: SITE REQUIREMENTS

3.2 Electrical and Power Requirements

3.2 ELECTRICAL AND POWER REQUIREMENTS

You must verify that the site conforms to the following electrical and power requirements.

3.2.1 Electrical Requirements

A certified electrician must make all electrical connections, and it's your responsibility to verify that the electrical installation of the machine meets all local regulations and electrical codes.

- **Primary Power Required** Single-Phase 230 Vac, 50/60 Hz
- **Recommended Circuit Amperage** Dedicated 20 A breaker

3.2.2 Power Requirements

If the site conforms to the electrical requirements, verify that it meets the following power requirements:

- **No Electrical Noise** Primary power must be provided by a dedicated circuit, which must be isolated from electrically-noisy devices like welders or plasma torches. The machine should be isolated from inductive loads from items like vacuum cleaners or air compressors.
- **No Ground Fault Circuit Interrupter** Power for the machine must not be protected by a ground fault circuit interrupter (GFCI), as it interferes with the operation of the variable frequency drive (VFD) spindle controller.
- **Proper Grounding** You must properly ground the power input to the machine. Examine the continuity between bare metal on the machine frame and true earth ground (a water pipe or similar) to verify that it's properly grounded.
- **Correct Plug Pattern** The machine is shipped with a NEMA 6-20P plug, designed for use with a NEMA 6-20R receptacle.

3.3 AIR REQUIREMENTS

- **Air Pressure** 90-120 psi (620-825 kPa)
If the air supply is more than 120 psi (825 kPa), you must use a regulator.
- **Air Volume** For successive, back-to-back tool changes, at least 2 cfm at 90 psi is required.
Exact air volume depends on the frequency of tool changes.
- **Dry Air** We recommend using a compressed air dryer, desiccator, or filter between the air compressor and the machine.
- **Lubricated Air** You must lubricate the air with air tool oil.
Use the pre-installed FRL Filter-Regulator-Lubricator for this purpose.

3: SITE REQUIREMENTS

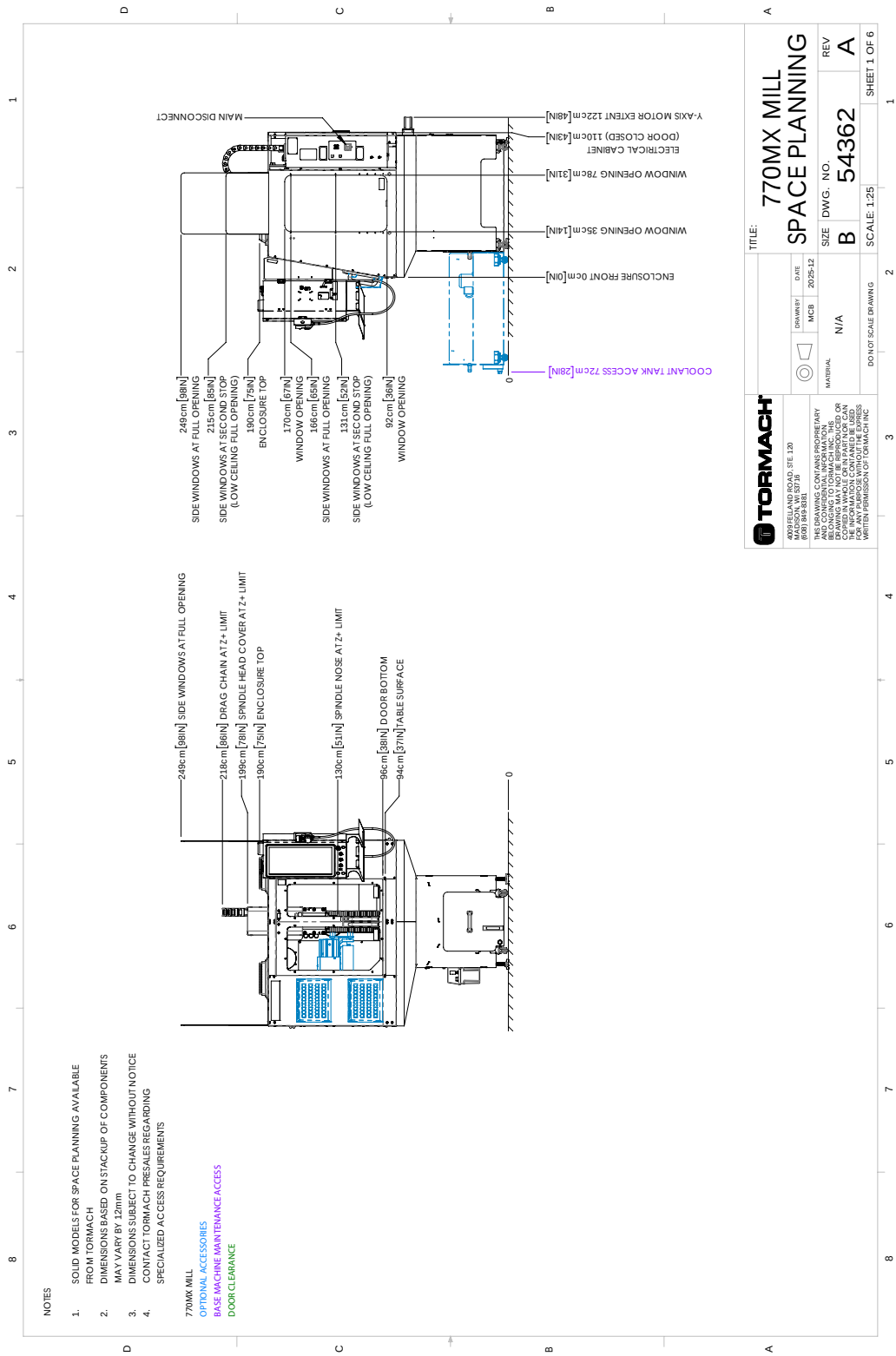
3.4 Space Planning Drawings

3.4 SPACE PLANNING DRAWINGS

3.4.1 Space Planning	39
3.4.2 Minimum Transport Height	41
3.4.3 Table Clearance	42
3.4.4 Table Details	43

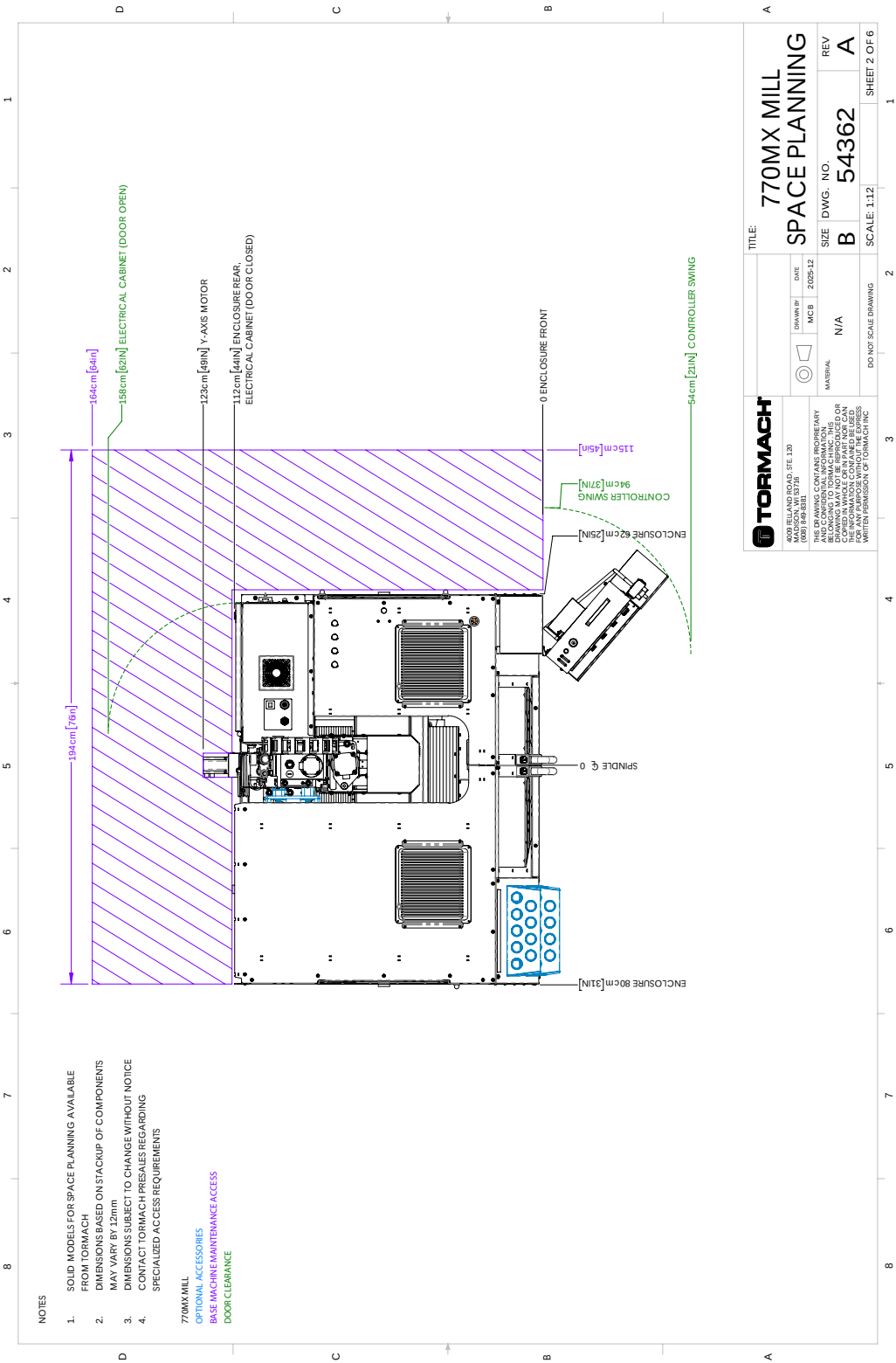
3.4.1 Space Planning

Front/Right Views

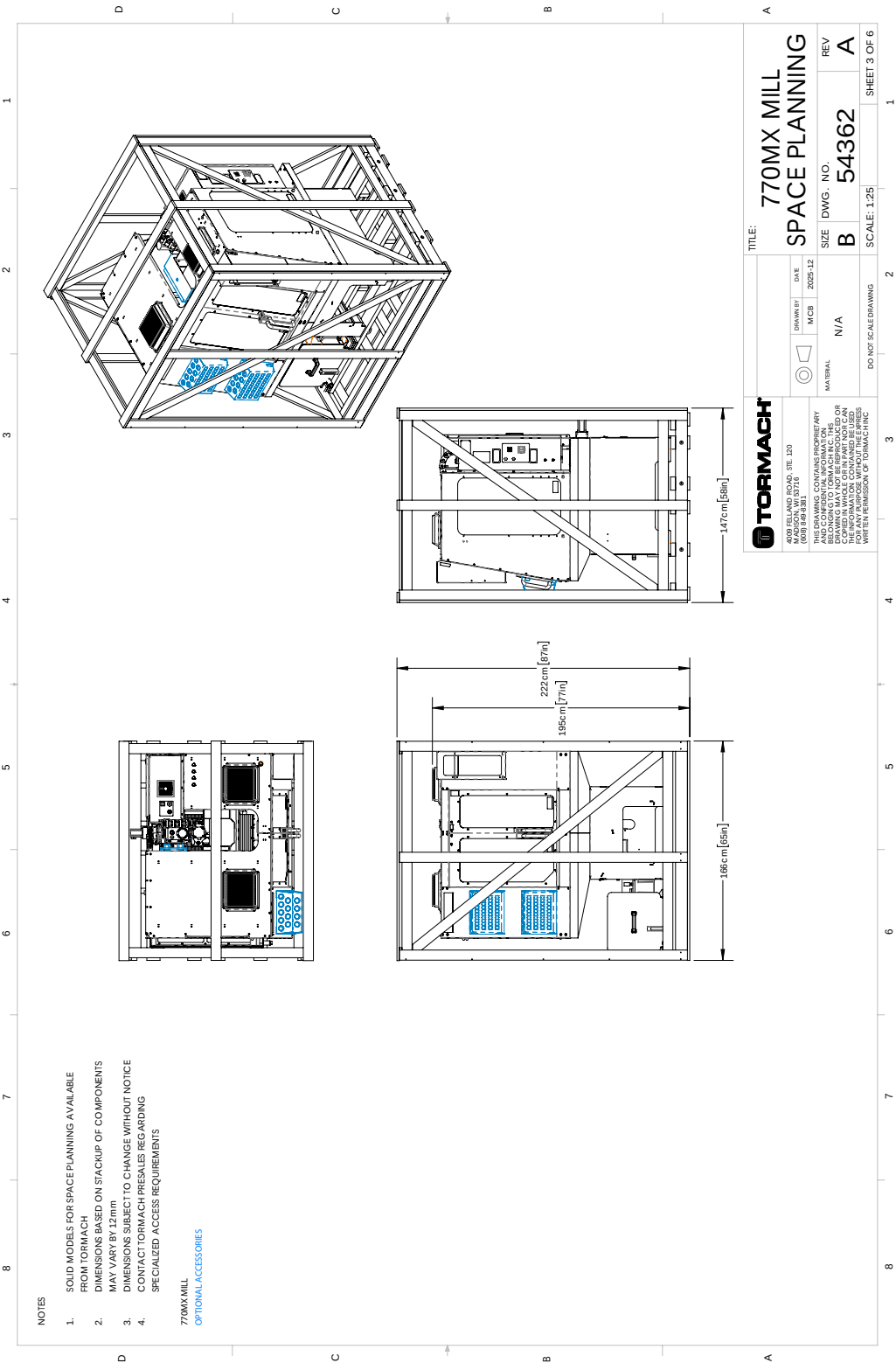


3: SITE REQUIREMENTS
3.4 Space Planning Drawings

Top View

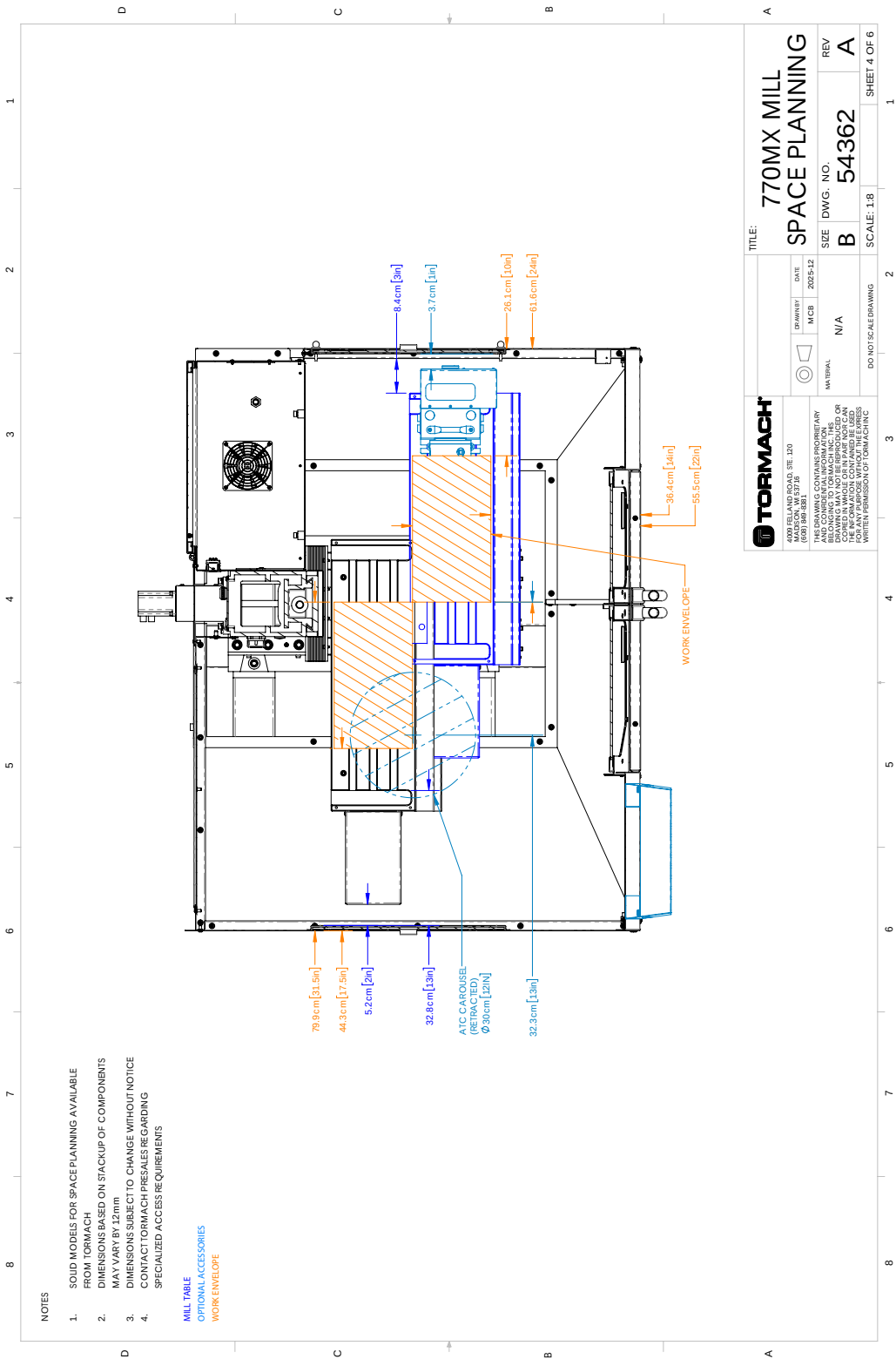


3.4.2 Minimum Transport Height

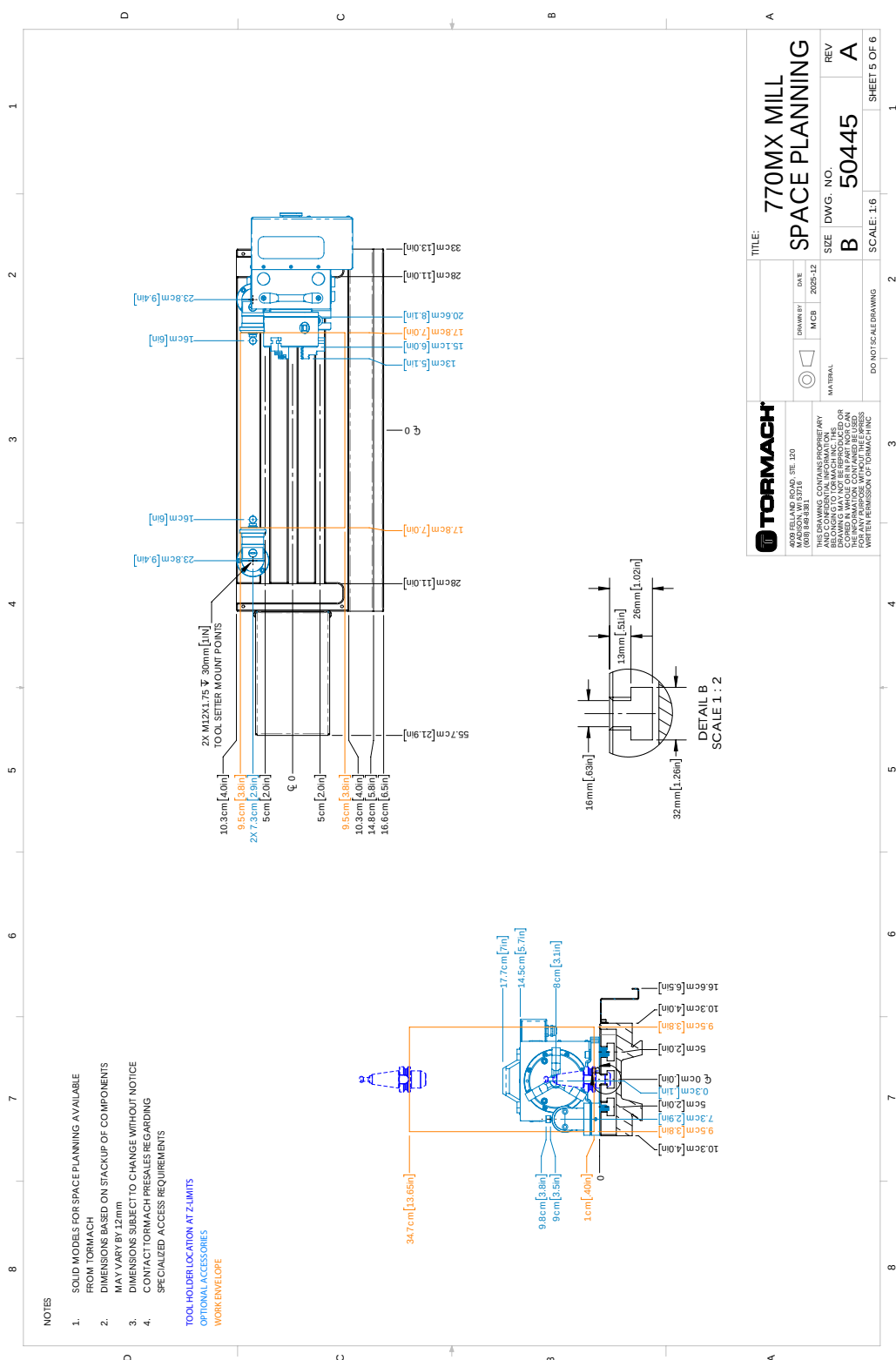


3: SITE REQUIREMENTS
3.4 Space Planning Drawings

3.4.3 Table Clearance



3.4.4 Table Details





INSTALLATION

IN THIS SECTION, YOU'LL LEARN:

- About the installation process required for this machine.

The installation of the base machine takes about four hours, not including items such as a Full Enclosure Kit or an Automatic Tool Changer (ATC).



Note: For ease of installation, don't install the chip pans, backsplash/splash guard, enclosure, or other accessories until after you've lifted the machine onto the Machine Stand.



Before operating the machine in any way, you must read and understand this section.

CONTENTS

4.1 Before You Begin	46
4.2 Installation Tools and Items	47
4.3 Move the Pallet	48
4.4 Self-Assembled Installation	49
4.5 Factory-Assembled Machine Setup	69
4.6 Verify the Installation	74
4.7 Install Accessory Components	78
4.8 Set Up the PathPilot Controller	99

4: INSTALLATION

4.1 Before You Begin

4.1 BEFORE YOU BEGIN

1. Inspect the item(s):

- Photograph any damage that may have occurred during shipping.
- Note any damage on the delivery receipt before signing for the shipment. If there is extensive visible damage to the machine, refuse to accept the shipment.
- Verify the received goods against the packing list.

If there is any damage or shortages, you must contact Tormach within 30 days of receipt. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

2. If there are any items that have not yet been delivered, we recommend waiting until you've received all shipments to begin installing the machine. Depending on the product and options ordered, the system may arrive in one or more shipments of:

- Accessories (if applicable)
- Machine



Note: The machine system and large accessories are sent by freight carrier. Smaller accessories may be sent by parcel service.

4.2 INSTALLATION TOOLS AND ITEMS

Before uncrating and beginning the initial setup of your machine, collect the following tools and items.

4.2.1 Required

- Assistant to help you
- Cable ties
- Consumables, like:
 - Air tool oil
 - Machine way oil
 - Sikaflex
- Cordless drill with a Phillips bit
- Hammer
- Level (2 ft)
- Lifting Bar Kit (PN 31446)
- Machinist stone
- Measuring tape
- Metric hex wrench set
- Pallet jack
- Phillips screwdriver
- Pry bar
- Reciprocating saw (or similar) to break down the pallet
- Safety eyewear that meets ANSI Z87+
- Shears or knife
- Socket set (imperial and metric)
- Step ladder
- Snips
- Work gloves

4.2.2 Optional

- Moving Kit (PN 31333)

4: INSTALLATION

4.3 Move the Pallet

4.3 MOVE THE PALLET

Shipments arrive in crates loaded on pallets, which the freight carrier unloads onto the curb or loading dock.



WARNING! Transportation and Lift Hazard: Before moving the machine, you must confirm that all persons are clear of the area below the machine. Qualified professionals must transport, lift, and move the machine. Moving parts can entangle, pinch, or cut you, causing death or serious injury.

- Verify that the ground surface is smooth and clean of debris, and then use a pallet jack to move the pallet(s) to the desired installation location.



Note: If the ground is not smooth, you may need to use a forklift (or similar lifting equipment rated for uneven surfaces) to move the pallet(s).

4.4 SELF-ASSEMBLED INSTALLATION

IMPORTANT! This section is for customers who are **assembling the machine themselves**. If you purchased the machine pre-assembled from the factory, you won't need to complete many of the procedures in this section. Go to "Factory-Assembled Machine Setup" (page 69) for information specific to factory-assembled machines.

Complete the following steps in the order listed:

4.4.1 Unpack the Machine Crate (Self-Assembled).....	49
4.4.2 Unpack the Stand Crate.....	49
4.4.3 Lift and Move the Machine.....	51
4.4.4 Set Up the PathPilot Operator Console.....	54
4.4.5 Install the Enclosure.....	54
4.4.6 Install the Oiler.....	67

4.4.1 Unpack the Machine Crate (Self-Assembled)

CAUTION! Sharp Objects Hazard: Before opening the shipping crate, you must put on work gloves and safety eyewear that meets ANSI Z87+. If you don't, the shipping crate and steel straps could cut you, causing serious injury.

1. Put on work gloves and eye protection.
2. Remove and discard the plastic packaging from the outside of the crate.
3. Remove the screws securing the top panel of the crate with a cordless drill and a Phillips bit. Lift the top panel off of the crate and set it aside.



Figure 4-1: Removing the top panel from the shipping crate.

4. With a helper, work your way around the crate, removing one panel at a time. Have your helper support the sides of the crate as you unscrew them.



Figure 4-2: Removing the side panels of the shipping crate.

5. Remove and discard the plastic bag from the outside of the machine.
6. Identify and remove the tool bag from the pallet.

4.4.2 Unpack the Stand Crate

CAUTION! Sharp Objects Hazard: Before opening the shipping crate, you must put on work gloves and safety eyewear that meets ANSI Z87+. If you don't, the shipping crate and steel straps could cut you, causing serious injury.

1. Remove the screws securing the top panel of the crate with a cordless drill and a Phillips bit. Lift the top panel off of the crate and set it aside.
2. With a helper, work your way around the crate, removing one panel at a time. Have your helper support the sides of the crate as you unscrew them.
3. Remove the shipping straps and protective packaging from the stand.

4: INSTALLATION

4.4 Self-Assembled Installation

- Slide the coolant tank out from the stand and set it aside. We recommend setting the coolant tank onto a piece of cardboard to protect the paint.



Figure 4-3: Removing the coolant tank from the stand.

- Cut the shipping straps on the coolant tank and remove the box.
- Open the box, which contains the coolant tank's casters, the machine feet, and the manual oiler. Set aside the machine feet and the manual oiler, which you'll need later in this procedure.
- Remove and set aside the chip tray. Then, stand the coolant tank on end to install the casters.
- Install the casters using four screws, washers, and a 6 mm hex wrench.



Figure 4-4: Installing the casters onto the coolant tank.

- Tilt the coolant tank down onto its casters, reinstall the chip tray, and roll the coolant tank aside temporarily.
- Remove the four bolts securing the machine stand to the pallet with a 9/16 in. socket wrench.



Figure 4-5: Removing the bolts securing the machine stand to the pallet.

- With a helper, pick the machine stand up off of the pallet and set it onto a piece of cardboard to install the feet. Place it onto its end, not its side.

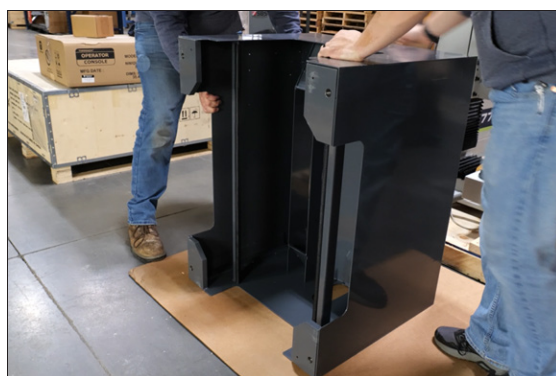


Figure 4-6: Placing the machine stand on its end on a piece of cardboard.

- Find the machine feet, nuts, and washers that you set aside earlier in this procedure. Install a nut and then a washer onto each foot.



Figure 4-7: Machine foot assembly.

- Thread the feet into each corner of the machine stand and tighten finger tight.

14. Adjust each foot so that the distance from the bottom of the machine stand to the bottom of the flat foot pad is 4 in. (10 cm). Then, tighten the nut finger tight against the washer.



Figure 4-8: Adjusting the height of the foot.

15. With a helper, tilt the machine stand up and set it onto its feet.
16. Roll the coolant tank back into the machine stand.

4.4.3 Lift and Move the Machine

For safety and security, use the [Lifting Bar Kit \(PN 31446\)](#) to lift the machine from above with an engine hoist or a gantry crane.



Note: If you're renting equipment to lift the machine, we recommend renting an gantry crane rather than an engine hoist.

1. Move the machine's pallet and stand as close as possible to the desired location with a pallet jack. The machine stand must be positioned behind the machine.
2. To allow room to position the engine hoist, you must first trim the left-hand side of the pallet (opposite from the electrical cabinet). Before you begin, clip up and move aside the oil line to prevent damage. Make sure the pallet is clear of any components near the cutting area.



WARNING! Power Tool Hazard: Operating a reciprocating saw could cause serious injury. Before operating the saw, you must put on hearing protection safety eyewear that meets ANSI Z87+. Keep hands and power cords clear of the blade, and work in an area without bystanders.

3. Put on safety eyewear and hearing protection. Then, cut the machine's pallet around the left-hand side of the pallet with a reciprocating saw (or similar). Make sure to cut only the pallet and not the support beam underneath the machine.



Figure 4-9: Trimming the left side of the machine's pallet.

4. Remove the four bolts securing the machine to the pallet with a 9/16 in. socket wrench.



Figure 4-10: Removing the bolts securing the machine to the pallet.

5. Remove the protective packaging from the machine table. Then, remove any excess shipping grease on the machine with a mild degreaser (like WD40® or similar).

4: INSTALLATION
4.4 Self-Assembled Installation

- 6. From the machine stand, remove the protective stickers from the pads. Then, stone the pads with a machinist stone to remove any burrs.



Figure 4-11: Removing the protective stickers from the pads on the machine stand.

- 7. Level the machine stand: Place a level onto the machine stand's pads, and adjust each foot until the stand is leveled.



Figure 4-12: Leveling the machine stand.

⚠ **WARNING!** Transportation and Lift Hazard: Before moving the machine, you must confirm that all persons are clear of the area below the machine. Qualified professionals must transport, lift, and move the machine. Moving parts can entangle, pinch, or cut you, causing death or serious injury.

- 8. Lift the machine from above. Complete the following steps in the order listed:

Required Tools.....52

Before You Begin..... 52

Assemble the Lifting Bar Kit..... 52

Connect the Machine for Lifting..... 53

Lift the Machine..... 53

Required Tools

This procedure requires the following tools. Collect them before you begin.

- Adjustable wrench
- Clean cloth
- Engine hoist

Before You Begin

1. Inspect the lifting chain for any broken links, and all other parts to make sure that there are no breaks or imperfections. If you find any broken links or imperfections, we can help. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.
2. Use a clean rag to remove any shipping grease from all components in the Lifting Bar Kit and from the surface of the machine table.

Assemble the Lifting Bar Kit

1. Find and identify the correct Lifting Bar Kit mounting holes specific to your machine:
 - On each end of the Lifting Bar Kit are the front and rear mounting holes: the front connects the lifting chain to the machine table, and the rear connects to the machine column itself.
 - In the center of the Lifting Bar Kit are two mounting holes: one for each mill model.

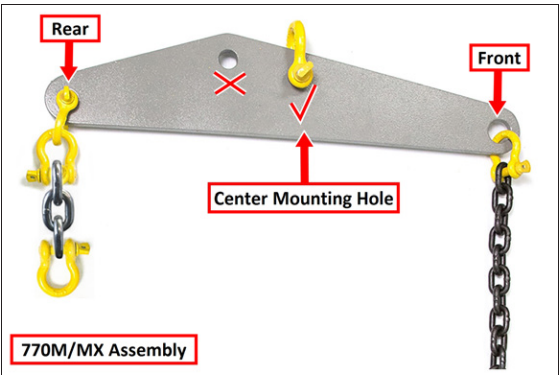


Figure 4-13: Center mounting hole on the Lifting Bar Kit.

2. Put one 3/8-in. forged lifting clevis and the lifting chain into the front mounting hole.

3. Depending on your machine, the center hole that you use varies. Put the 1/2-in. forged lifting clevis in the appropriate center mounting hole that you identified in Step 1.
4. Depending on your machine, the procedure for the rear mounting hole varies:
 - **770M/MX** Put two connected 3/8-in. forged lifting clevises, one three-link chain, and one 3/8-inch forged lifting clevis into the rear mounting hole.

Connect the Machine for Lifting

1. Move three M12 T-nuts into the front T-slot on the machine table and arrange them in the center as shown in the following image.



Figure 4-14: Lifting Bar Kit hardware arranged on the machine table.

2. Put the M12 lifting eye in the center M12 T-nut.
3. Securely tighten the M12 lifting eye with an adjustable wrench.
4. Put one M12 × 25 mm hex bolt and one M12 flat washer into the each of the remaining M12 T-nuts.
5. Securely tighten the two M12 × 25 mm hex bolts and two M12 flat washers with an adjustable wrench.
6. Connect the loose end of the lifting chain to the M12 lifting eye.
7. Connect the hook from your engine hoist to the center 1/2-in. forged lifting clevis on the lifting bar.
8. Depending on your machine, the procedure for connecting the lifting bar varies:
 - **770M/MX** Connect the lifting bar's rear 3/8-in. forged lifting clevis to the lifting bracket on the rear of the machine column.



Figure 4-15: Lifting Bar Kit connected to the machine.

Lift the Machine

1. Without yet lifting the machine, raise the engine hoist to remove any slack in the lifting chain.
2. Verify that the connections on the M12 hex bolts and the M12 lifting eye are securely tightened with an adjustable wrench.



WARNING! Tip Hazard: Before lifting the machine, you must verify that it's properly leveled. If the machine isn't level while it's lifted, the load on the engine hoist can unexpectedly slide, causing death or serious injury.

3. Slowly and steadily lift the machine to examine the alignment. The machine must lift flat and stay parallel with the floor, as shown in the following image.

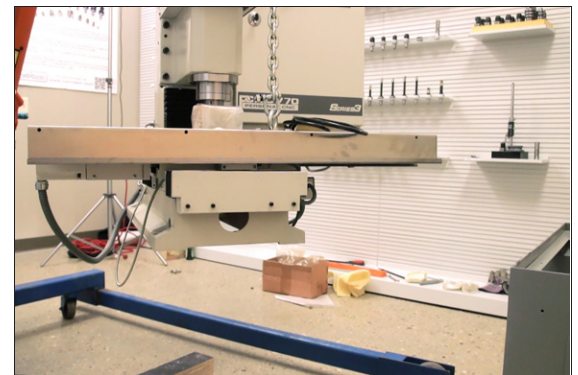


Figure 4-16: Machine lifted parallel to the floor.

If necessary, lower the machine and adjust the position of the M12 T-nuts.

4. Continue to lift the machine until it reaches the height at which it can clear the machine stand.

4: INSTALLATION

4.4 Self-Assembled Installation

- 5. Position the machine above the machine stand.
- 6. Slowly and steadily lower the machine on to the mounting pads on the machine stand, as shown in the following image.

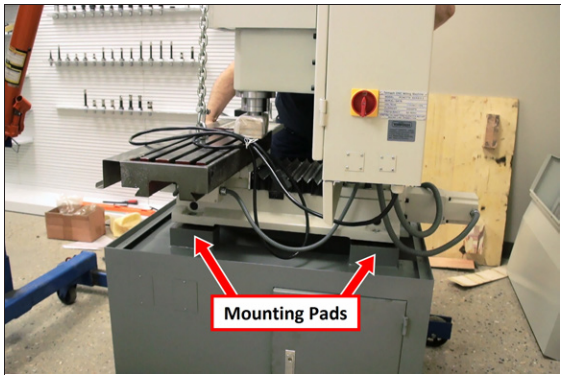


Figure 4-17: Machine lowered on to the mounting pads on the machine stand.

WARNING! Crush Hazard: While lowering the machine onto the machine stand, you must keep your hands away from all moving parts. Moving parts can entangle, pinch, or cut you, causing death or serious injury.

- 7. Secure the machine to the machine stand with a 10 mm hex wrench, four M12 × 50 mm socket head cap screws, and four M12 washers.
- 8. Once the machine is completely supported by the machine stand, remove all components of the Lifting Bar Kit.

4.4.4 Set Up the PathPilot Operator Console

To verify the installation of the base machine, you must use the PathPilot controller. We recommend that you temporarily set up the PathPilot operator console now.

Note: Wait to complete the full assembly of the console until after you've installed all other major accessories.

- 1. Open the PathPilot operator console box and remove the operator console.
- 2. Lay the control console down on the work surface to prevent tipping.
- 3. Remove and set aside the three screws securing the

operator console's front panel with a 2 mm hex wrench.

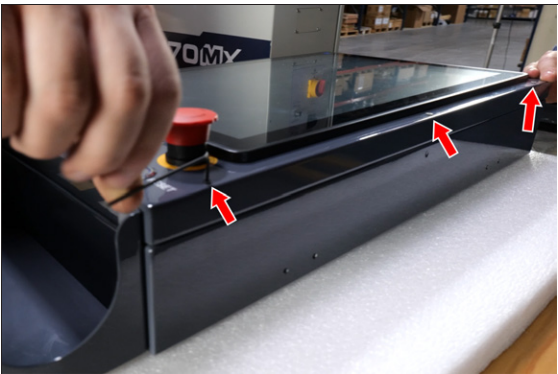


Figure 4-18: Opening the operator console's front panel.

- 4. Open the operator console's hinged front panel, and make the following connections on both the operator console and the machine:
 - Connect the power supply cable to the controller, and connect the loose end of the power cable to the **Console Power** outlet on the side of the electrical cabinet.
 - Connect the Ethernet cable to the LAN 1 port on the controller, and connect the loose end of the cable to the **Controller Communications** connector on the top of the electrical cabinet.
 - Connect the emergency stop cable to the back of the operator console, and connect the loose end of the cable to the **Emergency Stop** connector on the top of the electrical cabinet.
 - Connect the jog pendant cable to the back of the operator console.
- 5. Prop up the console to avoid pinching the cables.

4.4.5 Install the Enclosure

Before You Begin Assembly.....	55
Required Tools.....	55
Unpack the Enclosure Crate.....	55
Install the Chip Pans.....	56
Prepare the Sealant.....	56
Apply Sealant and the Install Chip Pans.....	56
Install the Enclosure Panels.....	56
Install the Left Rear Panel.....	56
Install the Left Side Panel.....	57
Install the Left Front Panel.....	57
Install the Enclosure Splice Plate.....	57

Install the Right Rear Panel	57
Install the Right Side Panel	58
Install the Right Front Panel	58
Install the Left Top Panel	58
Install the Right Top Panel	58
Install the Upper Front Panel	59
Install the Front Lower Panel	59
Install the Rear Splash Shield	59
Install the Front Doors	59
Install the Linear Rail Assemblies	59
Install Door Assemblies	60
Install the Door Latch	61
Install the Side Windows	62
Install the Floodlights	62
Install the Access Panel	62
Install the Stainless Steel Wear Guard	63
Use the Maintenance Labels	64
Replace the Windows	64
Mount the Operator Console	64
Apply Sealant to the Enclosure	65
Prepare the Enclosure	65
Tape the Seams	65
Prepare the Sealant	66
Apply Sealant	66
Cure and Test	66
Install the Air Gun	66

 **Note:** If you plan to install the ATC (automatic tool changer) now, you may find it easier to mount the ATC before proceeding with the enclosure installation (refer to "Install the Automatic Tool Changer (ATC)" (page 78) for more information). The ATC is slightly easier to mount when the enclosure panels are not yet installed, as you'll have better access to the mounting area.

Before You Begin Assembly

1. Inspect the item(s):
 - Photograph any damage that may have occurred during shipping.
 - Verify the received goods against the packing list.

If there is any damage or shortages, you must contact Tormach within 30 days of receipt. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

2. Read the packing list and locate all items. During the installation, remove labels from the items as needed.
3. If you plan to use flood coolant, we recommend using Sikaflex to seal the enclosure. Refer to the manufacturer's specifications for details on use and cure time. After the sealant is completely cured, test the enclosure for leaks and identify any areas requiring extra sealant.

 **Tip!** Keep all screws one quarter-turn loose while installing the enclosure panels. This makes it easier to align the panels. Once you're done installing the enclosure, fully tighten all screws.

Required Tools

- Caulk gun
- Metric hex wrench set
- Safety eyewear that meets ANSI Z87+
- Denatured alcohol for excess sealant cleanup
- Rubber gloves for working with sealant
- Shears or knife
- Shop rags
- Work gloves

Unpack the Enclosure Crate

 **CAUTION!** Sharp Objects Hazard: Before opening the shipping crate, you must put on work gloves and safety eyewear that meets ANSI Z87+. If you don't, the shipping crate and steel straps could cut you, causing serious injury.

1. Put on work gloves and eye protection.
2. Cut and remove the steel straps on the shipping crate with snips.
3. Disassemble the shipping crate with a hammer and pry bar. Start with removing the top, followed by the four sides.

4: INSTALLATION

4.4 Self-Assembled Installation

Install the Chip Pans

Prepare the Sealant

CAUTION! Chemical Exposure Hazard: Sealant and cleaning solvents may cause skin and eye irritation. Wear disposable gloves and safety eyewear. Use in a well-ventilated area and avoid contact with skin and eyes.

1. Put on disposable rubber gloves.
2. Puncture the inner seal of the Sikaflex tube, install the nozzle, and cut the tip to create an opening approximately 1/4 in. (6 mm).
3. Install the tube into a caulk gun.

Apply Sealant and the Install Chip Pans

IMPORTANT! Complete the sealant application in one continuous work session. Do not begin applying sealant unless you can finish all applications without interruption. If the sealant cures before the enclosure is fully assembled and tightened, the panels may bond in place and prevent proper alignment.

1. Apply a thin, continuous bead of sealant along the top lip on the right side of the machine stand. Verify that the bead has continuous coverage with no visible gaps.
2. Install the right side chip pan to the machine stand with seven M6 × 1.0 - 12 screws.

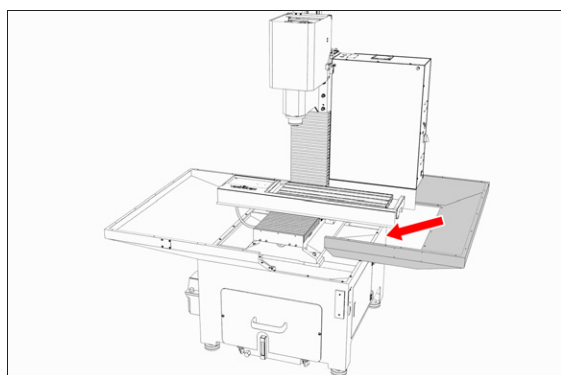


Figure 4-19: Right-hand chip pan aligned with the Machine Stand.

3. Apply a thin, continuous bead of sealant along the top lip on the left side of the machine stand. Verify that the bead has continuous coverage with no visible gaps.
4. Apply a thin, continuous bead of sealant along bottom edge of the right chip pan at the seam between the two chip pans.
5. Install the left side chip pan to the machine stand with seven M6 × 1.0 - 12 screws.

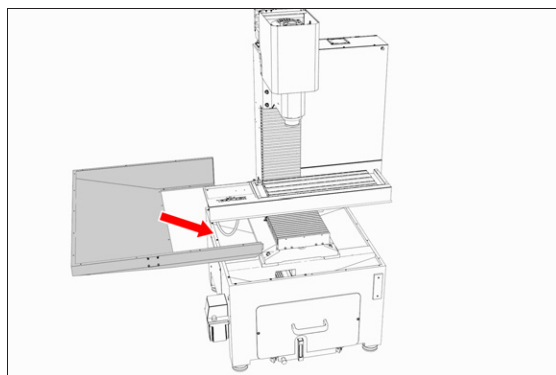


Figure 4-20: Left-hand chip pan aligned with the Machine Stand.

6. Secure the seam between the two chip pans with four M6 × 1.0 - 12 screws.
7. Install the chip pan access panel (PN 54585) on the back right (below the electrical cabinet) with two M6 × 1.0 - 12 screws.

Install the Enclosure Panels

IMPORTANT! Install the remaining enclosure panels loosely before applying sealant. Do not apply sealant while installing individual panels. We recommend applying sealant to all seams **after** the enclosure is fully assembled and aligned.

Install the Left Rear Panel

1. Attach the column cover (PN 37618) to the machine column with three M6 × 1.0 - 12 screws.
2. Attach the left rear panel (PN 37616) to the column cover with three M5 × 0.8 - 10 screws.

3. Attach the left rear panel to the left chip pan with four M6 × 1.0 - 12 screws.

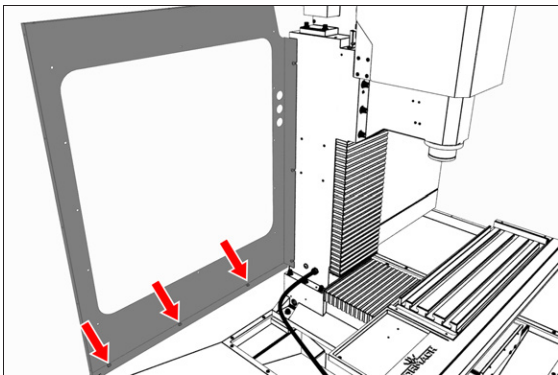


Figure 4-21: Left rear panel attached to the left chip pan.

Install the Left Side Panel

1. Attach the left side panel (PN 54368) to the left rear panel with five M5 × 0.8 - 10 screws.

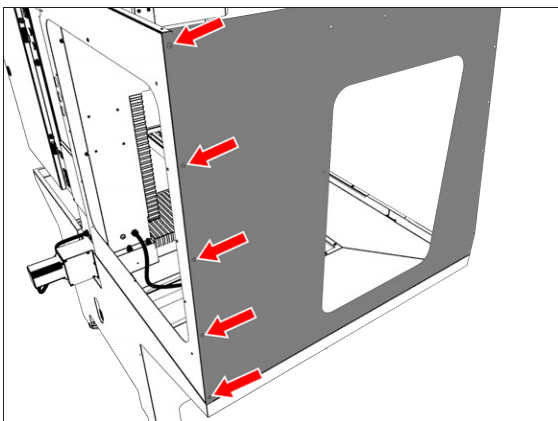


Figure 4-22: Left side panel attached to the left rear panel.

2. Attach the left side panel to the left chip pan with five M6 × 1.0 - 12 screws.

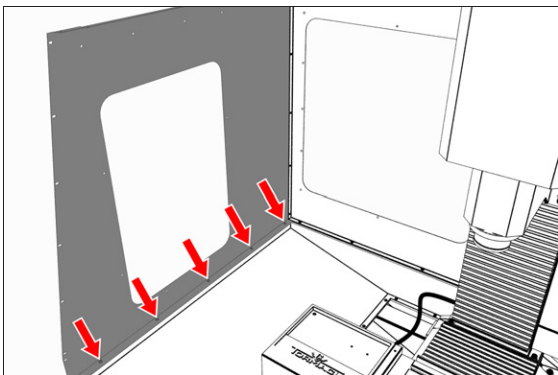


Figure 4-23: Left side panel attached to the left chip pan.

Install the Left Front Panel

1. Attach the left front panel (PN 39551) to the left chip pan with three M6 × 1.0 - 12 screws.

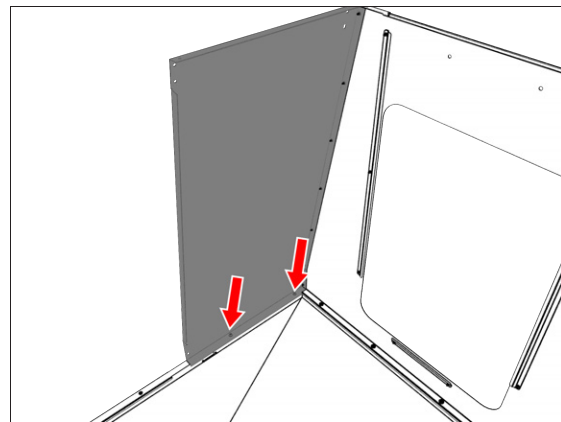


Figure 4-24: Left front panel attached to the left chip pan.

2. Attach the left front panel to the left side panel with seven M5 × 0.8 - 10 screws.

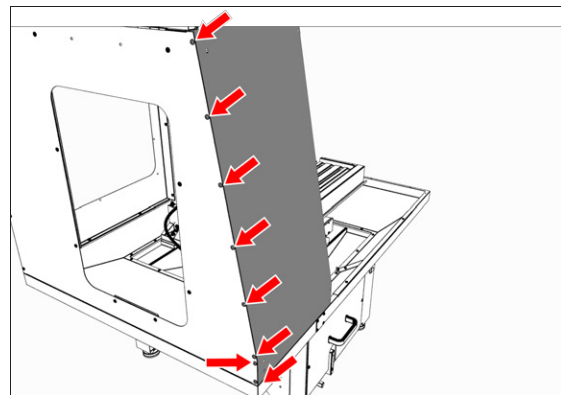


Figure 4-25: Left front panel attached to the left side panel.

Install the Enclosure Splice Plate

1. Find the three installed M5 × 0.8 - 10 screws on the right side of the electrical cabinet.
2. Remove and set aside the three M5 × 0.8 - 10 screws.
3. Attach the right rear side panel (PN 37619) to the electrical cabinet with the three M5 × 0.8 - 10 screws that you set aside in Step 2.

Install the Right Rear Panel

1. Find the three installed M5 × 0.8 - 10 screws along the top of the electrical cabinet.
2. Remove and set aside the three M5 × 0.8 - 10 screws.

4: INSTALLATION

4.4 Self-Assembled Installation

3. Attach the right rear top panel (PN 38480) to the electrical cabinet with the three M5 × 0.8 - 10 screws that you set aside in Step 2.

Install the Right Side Panel

1. Attach the right side panel (PN 54367) to the enclosure splice plate with four M5 × 0.8 - 10 screws.
2. Attach the right side panel to the right chip pan with four M6 × 1.0 - 12 screws.

Install the Right Front Panel

1. Attach the right front panel (PN 54332) to the right chip pan with two M6 × 1.0 - 12 screws.

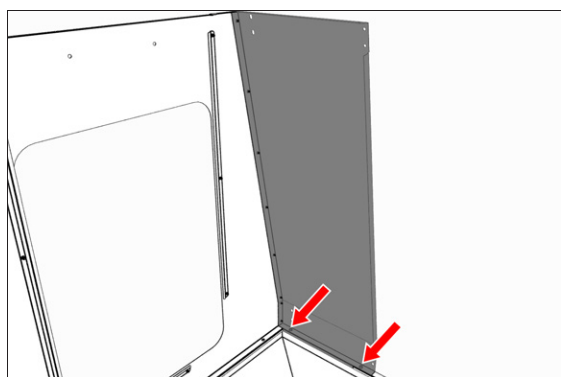


Figure 4-26: Right front panel attached to the right chip pan.

2. Attach the right front panel to the right side panel with seven M5 × 0.8 - 10 screws.

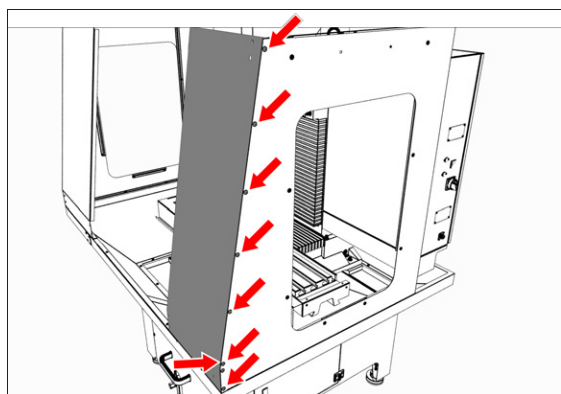


Figure 4-27: Right front panel attached to the right side panel.

Install the Left Top Panel

1. Attach the left top panel to the panels on the left side of the enclosure with 12 M5 × 0.8 - 10 screws.

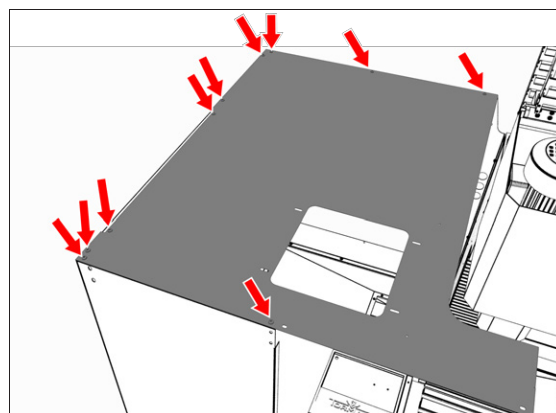


Figure 4-28: Left top panel attached to the left side of the enclosure.

Install the Right Top Panel

1. Attach the right top panel (PN 54339) to the panels on the right side of the enclosure with nine M5 × 0.8 - 10 screws.

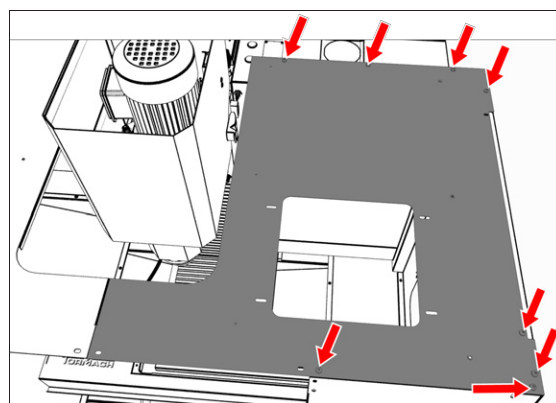


Figure 4-29: Right top panel attached to the right side of the enclosure.

2. Connect the left and right top panels with one M5 × 0.8 - 10 screw.

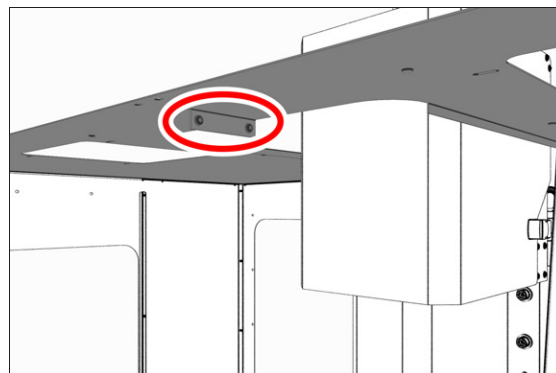


Figure 4-30: Left and right top panels connected.

Install the Upper Front Panel

1. Attach the front upper panel (PN 37605) (with the threaded holes facing up) to the right and left front panels with two sets of two M5 × 0.8 - 10 screws.

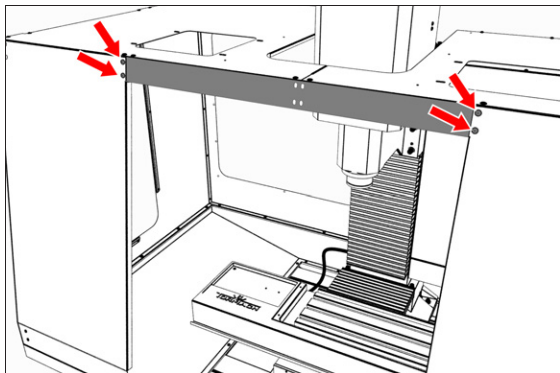


Figure 4-31: Front upper panel attached to the right and left front panels.

2. Attach the front upper panel to the right and left top panels with four M5 × 0.8 - 10 screws.

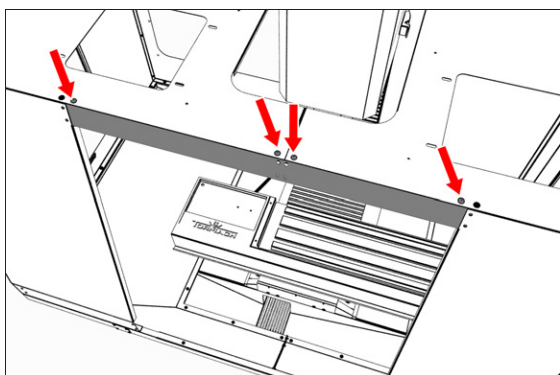


Figure 4-32: Front upper panel attached to the right and left top panels.

Install the Front Lower Panel

1. Attach the front lower panel (PN 54399) to the right and left front panels with two sets of two M5 × 0.8 - 10 screws.

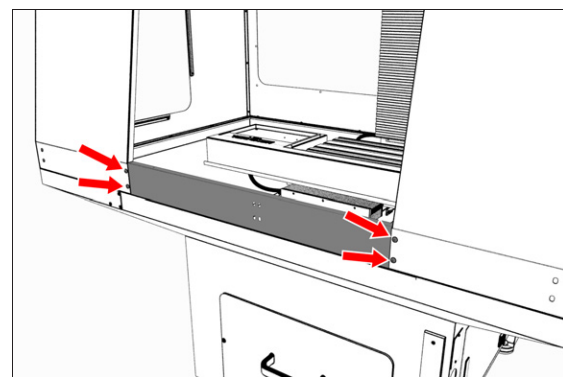


Figure 4-33: Front lower panel attached to the right and left front panels.

2. Attach the front lower panel to the right and left chip pans with four M5 × 0.8 - 10 screws.

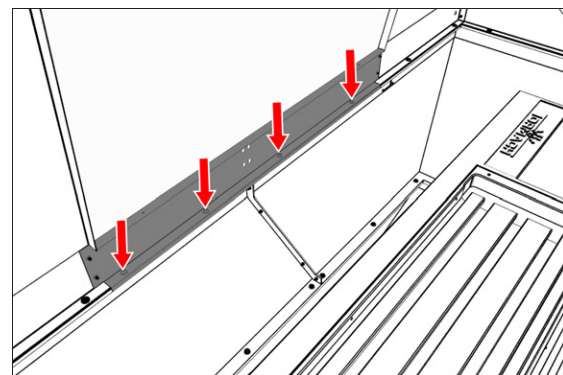


Figure 4-34: Front lower panel attached to the right and left chip pans.

Install the Rear Splash Shield

- Attach the rear splash shield to the right chip pan below the electrical cabinet with four M6 × 1.0 - 12 screws.

Install the Front Doors

Install the Linear Rail Assemblies

1. Align one short linear rail assembly (PN 37607) to the two holes on the inside of both the right front panel and the front lower panel.
The linear rail mount's clamping screws must face up.

4: INSTALLATION

4.4 Self-Assembled Installation

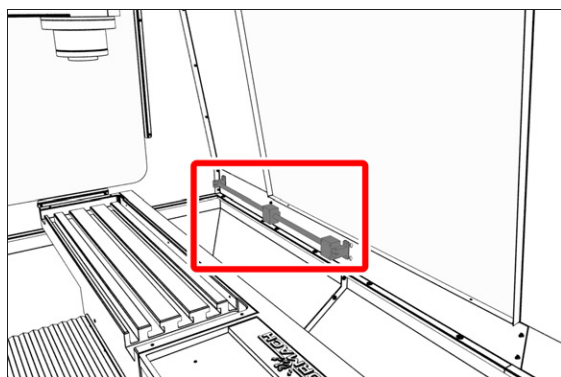


Figure 4-35: Right lower linear assembly attached to the inside of the enclosure's lower right side.

2. Attach the short linear rail assembly to the outside of both the right front panel and the front lower panel with two sets of two M6 × 1.0 - 12 screws.

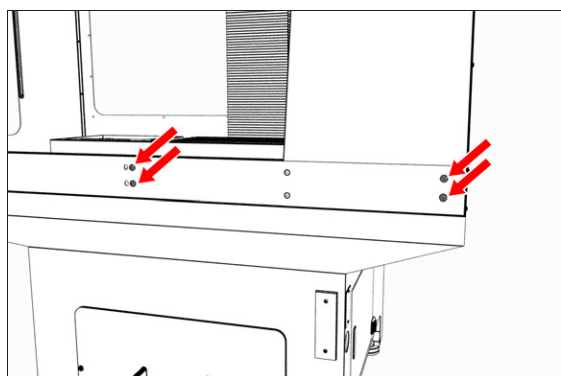


Figure 4-36: Right lower linear assembly attached to the outside of the enclosure's lower right side.

3. Repeat Steps 1 to 2 for the remaining three linear rails, with the linear rail mount's clamping screws face in the following directions:
 - Up on the lower linear assemblies
 - Down on the upper linear assemblies

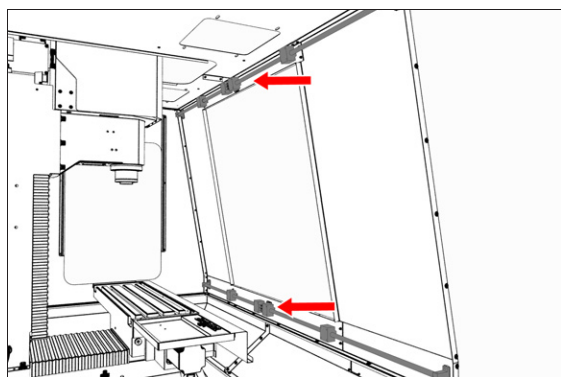


Figure 4-37: Four linear assemblies attached to the enclosure.

Install Door Assemblies

Each front door is attached to the enclosure by securing it to the linear bearings: the wider door is mounted on the left side of the enclosure, and the narrower door is mounted on the right side of the enclosure.

To install the front doors:

1. Starting with the top linear assembly, attach the narrow door to the two upper linear bearings with two sets of four M5 × 0.8 - 10 screws.

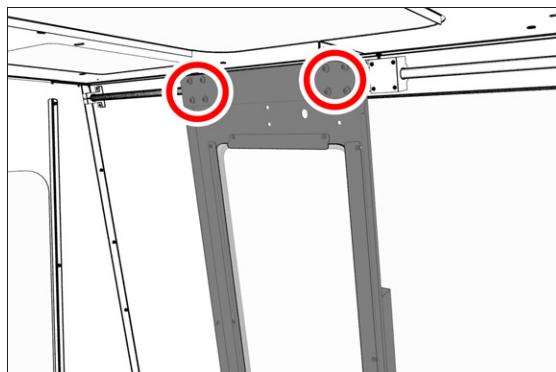


Figure 4-38: Narrow door attached to the top linear assembly.

2. Move the bottom of the narrow door into alignment with the bottom linear assembly. Then, attach the narrow door to the two bottom linear bearings with two sets of four M5 × 0.8 - 10 screws.
3. Repeat Steps 1 to 2 to attach the wide door to the top and bottom linear rail assemblies on the remaining side of the enclosure.

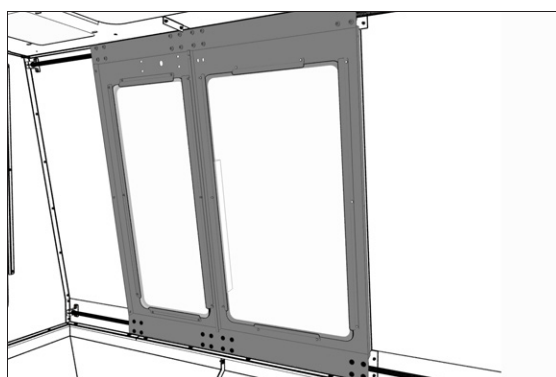


Figure 4-39: Both front doors attached to the enclosure.

4. To the edge of the front door that's closest to the left side of the enclosure, attach one door seal with three M5 × 0.8 - 10 screws.

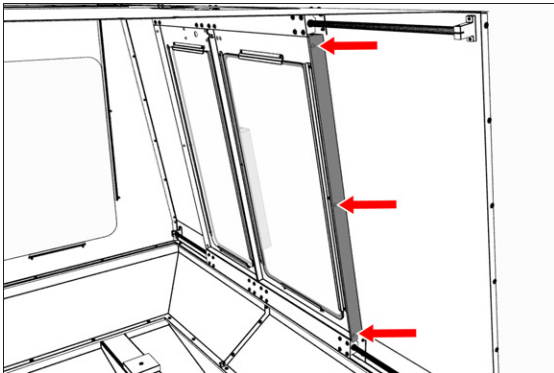


Figure 4-40: Door seal attached to the edge of the front door.

5. Repeat Step 4 for the remaining front door.
6. Attach the handles to both front doors with two sets of two M8 x 1.25 - 20 screws and two sets of two M8 flat washers.

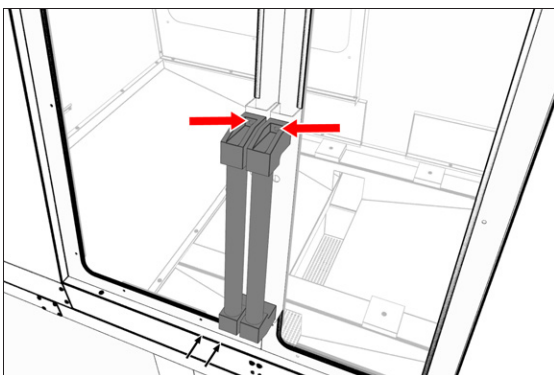


Figure 4-41: Both front door handles attached to the enclosure.

7. Push one square tube plug into the bottom of each door handle.

Install the Door Latch

1. Install the latch plate on the top inside surface of the left door using two M6 screws. Thread the screws finger tight only, as you'll need to adjust the alignment in the following steps.
2. Install the door lock switch plate on the top inside surface of the right door using 2 M6 screws. Thread the screws finger tight only.
3. Roughly center the lock plate vertically in the adjustment slots.

4. Slowly close the left door and observe whether the switch plate (the switch mechanism itself) aligns with the latch plate. The latch should engage the switch smoothly. Adjust the position of the latch plate as needed, then tighten its screws securely.
5. Fully close both doors to lock the switch. Check for gaps in the enclosure where the doors meet. If there is a gap, adjust the position of the switch plate to eliminate it, then tighten the switch plate screws securely.
6. Test the door lock mechanism: Use the manual override (with a hex wrench) to unlock the door switch. Open and close the doors several times to verify that the switch locks and unlocks easily.
7. Connect the two loose ends from the door switch button to the door switch itself. Ensure connections are secure.
8. Locate the grommet for the door switch cable. Push the grommet into the open hole on the top of the enclosure (nearest to the operator console mount location).
9. Route the door switch cable through the grommet to the top of the enclosure. Pull the cable through until there is minimal slack, but leave enough length so that the doors can freely open and close through their full range of motion.
10. Secure the cable inside the enclosure using zip ties:
 - Place one zip tie on the latch plate to secure the cable
 - Place one zip tie on the inside of the top enclosure panel
 - Place one zip tie to bundle the cable and wires together



Tip! Consider the full travel range of the doors when positioning zip ties to avoid creating tension points.

11. Route the loose end of the door switch cable along the top of the enclosure toward the electrical cabinet. Wait to secure this cable with zip ties until after you've installed the operator console, as you'll be routing additional cables along the same path and can manage them all together for a tidier installation.

4: INSTALLATION

4.4 Self-Assembled Installation

12. Open the electrical cabinet door, route the door switch cable through the access panel in the side of the electrical cabinet, and connect it to the Machine Door bulkhead connector. Close the electrical cabinet door.

Install the Side Windows

1. Remove the plastic film from each side of the window and discard it.
2. Slide each window into the side panel, making sure that the sticker is facing toward you.
3. You can use two of the window stoppers temporarily while you're installing the handle. Slide it onto the center of the bottom of the window.
4. When you're done using the window stoppers and want to close the window, there are two holes on the side of the window to store the stoppers.

Install the Floodlights

1. Use a multimeter to verify the ground connection of both floodlights:
 - a. Measure the resistance between the floodlight's power connector ground pin (the middle pin on the three-prong connector) and the floodlight's bracket screw.
 - b. Read the OHMS value that displays. The value should be less than 5 OHMS. If the value is greater than 5 OHMS, don't install the floodlight. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.
2. Position one floodlight over the opening on the right top panel. Take care not to drop the light through the opening into the enclosure.
3. Attach one floodlight retainer to either side of the lights with two sets of two M5 × 0.8 - 10 screws. Verify that the floodlight is centered over the opening before hand-tightening the floodlight retainers.

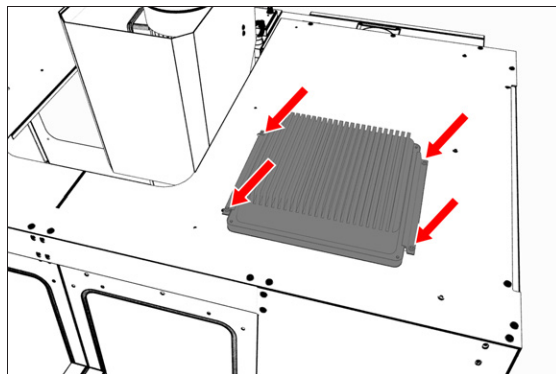


Figure 4-42: Floodlight attached to the top panel.

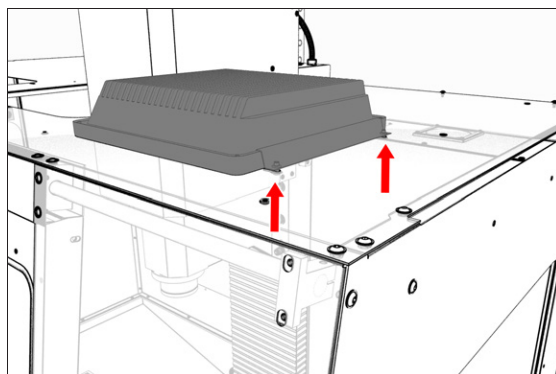


Figure 4-43: Attached floodlight from the inside of the enclosure.

4. Repeat Steps 1 to 3 to install the floodlight on the left side.
5. Connect the short power cable from the Enclosure Cable Kit to the plug on the right floodlight.
6. Connect the long power cable from the Enclosure Cable Kit to the plug on the left floodlight.
7. Route the power cables from the floodlights to the electrical cabinet.
8. Plug the floodlights into the Enclosure Lights outlet on the back of the electrical cabinet.
9. Attach the floodlights' power cables to the five wire tie anchors on the left and right top panels with five wire ties.

Install the Access Panel

1. Push three round hole plugs into the three holes on the left rear panel.

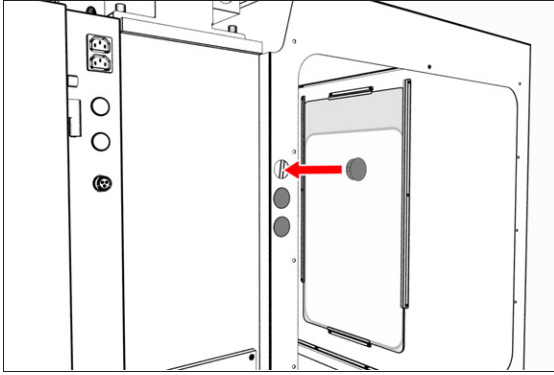


Figure 4-44: Round hole plugs pushed into the left rear panel.

2. Push a strip of rubber trim to the edge of the access panel opening on the left rear panel. Verify that the trim covers the entire perimeter of the opening. When finished, use shears or a knife to cut the excess trim.
3. Find the threaded hole toward the top center of the left rear panel. Then, loosely install one M5 × 0.8 - 10 screw from the inside of the enclosure. This screw supports the access panel while you install the remaining fasteners.

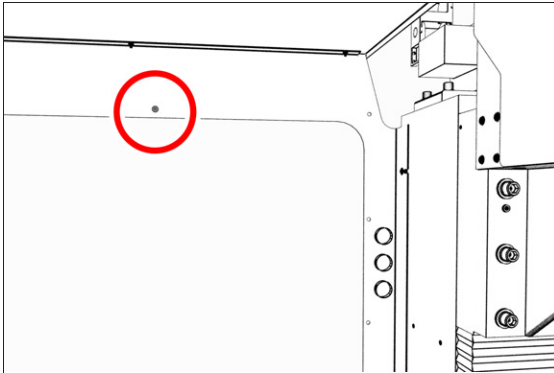


Figure 4-45: Supporting screw inside the left rear panel.

4. Tilt the access panel and put it through the opening on the left rear panel. Then, hang it inside the enclosure on the installed M5 × 0.8 - 10 screw.

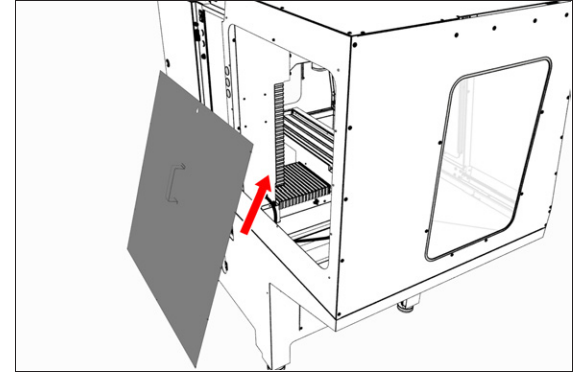


Figure 4-46: Access panel moving inside the enclosure.

5. Attach the access panel to the left rear panel from the outside of the enclosure with 11 M5 × 0.8 - 10 screws.

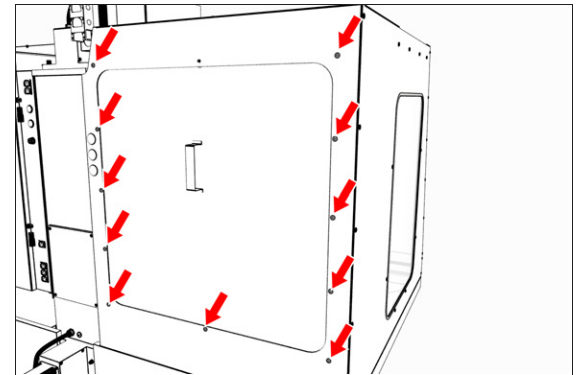


Figure 4-47: Access panel attached to the left rear panel.

Install the Stainless Steel Wear Guard

- Find the stainless steel wear guard that you set aside earlier. Attach it to the lower front panel with two M5 × 0.8 - 10 screws.

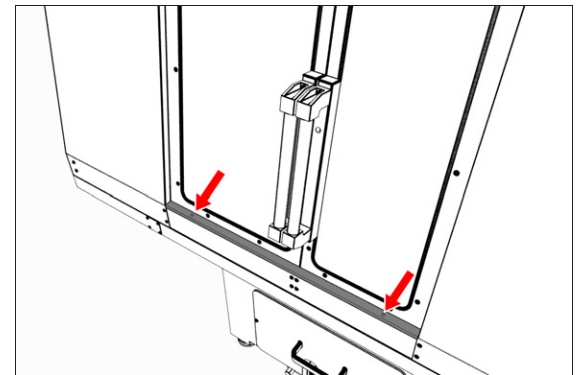


Figure 4-48: Stainless steel wear guard attached to the lower front panel.

4: INSTALLATION

4.4 Self-Assembled Installation

Use the Maintenance Labels

The machine has one maintenance label on each window.



Figure 4-49: Window maintenance label.

- Write down today's date on each label with a permanent marker.

You have completed assembling and installing the 770MX Enclosure.

Replace the Windows

When required, replace the windows with the following parts:

- Window, 770, Side (PN 37625)
- Window, 770M, Left Door (PN 37623)
- Window, 770M, Right Door (PN 37624)

Mount the Operator Console

1. Disconnect the three cables (power, Ethernet, and emergency stop) from the machine that you previously connected.
2. Install the two hinges onto the back of the operator console. The short side of each hinge attaches to the operator console.



Figure 4-50: Installing the hinges onto the operator console.



Note: The hinges are stiff and require bending to the proper angle. We recommend using an adjustable wrench to carefully bend each hinge to approximately 90 degrees before proceeding.

3. With an assistant, lift the operator console and position

it onto the console mount on the right side of the enclosure. One person should support the weight while the other aligns the hinges with the mounting holes.

Secure the console to the mount.



Figure 4-51: Mounting the operator console onto the enclosure.

4. Route the loose end of the power, Ethernet, and emergency stop cables to the back of the enclosure. These cables route through the rectangular opening in the operator console mount and then up through the circular opening on the top of the mount. The operator console's power brick should rest on the inside ledge of the mount for support.



Figure 4-52: Routing the cables through the top operator console mount and to the top of the enclosure.

- To route the jog pendant cable through the mount, you'll need to temporarily disassemble the DB25 connector: Remove the connector cover plate and set it aside.



Figure 4-53: Disassembling the jog pendant's DB25 connector.

- Route the cable through the circular opening on the bottom of the mount.



Figure 4-54: Routing the jog pendant cable through the bottom of the operator console mount.

- Reassemble the jog pendant's DB25 connector, and connect it to the back of the operator console.
- Route the ATC USB cable from the back of the machine and through the openings on the operator console mount.
- Bundle the cables inside the operator console mount together using zip ties.
- Install the mouse panel onto the front of the operator console using two M4 screws. Place the keyboard and mouse onto the panels.
- Install the jog shuttle panel onto the front of the operator console using two M4 screws. Place the jog pendant (which is magnetic) onto the panel.
- Open the operator console's hinged front panel.
- Route the loose ends of the USB cables from the

keyboard, mouse, and (if equipped) ATC into the operator console. Connect them to the USB ports on the controller.

Tip! If you have a hardwired Ethernet connection for network access (not required for machine operation), connect it to the LAN 2 port inside the operator console now.

- Close and secure the operator console's hinged front panel.
- Route the Emergency Stop cable, the Ethernet cable, and the operator console's power cable along the top of the enclosure and to the electrical cabinet.
- Connect the Emergency Stop cable to the **Emergency Stop** connector on the top of the electrical cabinet.
- Connect the Ethernet cable to the **Controller Communications** connector on the top of the electrical cabinet.
- Connect the operator console's power cord to the **Console Power** outlet on the side of the electrical cabinet.
- Bundle all of the cables on the top of the enclosure together, using zip ties at regular intervals to secure them neatly. If you haven't already done so, now is a good time to secure the door switch cable that you routed earlier.

Apply Sealant to the Enclosure

Prepare the Enclosure

- Using a 3 mm hex wrench, loosen the enclosure screws from the chip pans upward.
 - Loosen only the screws that join enclosure panels together; do not loosen the screws that secure the doors.
 - Loosen screws along panel-to-panel seams, chip pan seams, top panels, and seams adjacent to the electrical cabinet.
- Verify that each seam can separate slightly.

Tape the Seams

- Apply painter's tape along both sides of each seam to be sealed (between chip pans and panels, the front, side, and rear panels, the lower front enclosure panel, and

4: INSTALLATION

4.4 Self-Assembled Installation

panels adjacent to the electrical cabinet). Make sure to place the tape only on the panel surfaces, leaving the seams fully exposed.

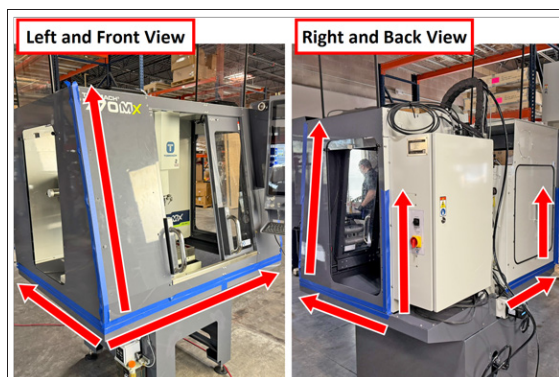


Figure 4-55: Enclosure panels' seams lined with painter's tape.

Prepare the Sealant

CAUTION! Chemical Exposure Hazard: Sealant and cleaning solvents may cause skin and eye irritation. Wear disposable gloves and safety eyewear. Use in a well-ventilated area and avoid contact with skin and eyes.

1. Put on disposable rubber gloves.
2. Puncture the inner seal of the Sikaflex tube, install the nozzle, and cut the tip to create an opening approximately 1/4 in. (6 mm).
3. Install the tube into a caulk gun.

Apply Sealant

IMPORTANT! Complete the sealant application in one continuous work session. Do not begin applying sealant unless you can finish all applications without interruption. If the sealant cures before the enclosure is fully assembled and tightened, the panels may bond in place and prevent proper alignment.

1. Apply a thin, continuous bead of sealant along each taped seam around the enclosure. Insert the nozzle slightly into the seam while dispensing sealant, making sure it's pushed between the panels rather than deposited on the surface.

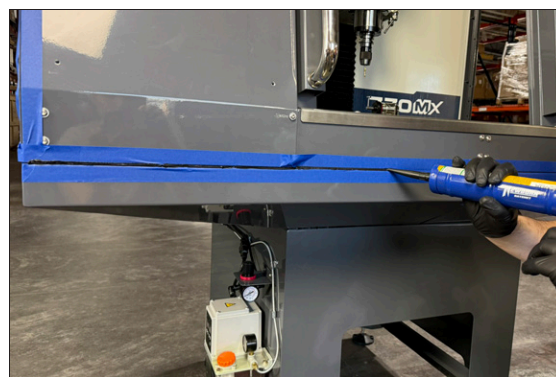


Figure 4-56: Applying a bead of sealant to the seam between the panels and the chip pan.

2. Verify that all seams have continuous coverage with no visible gaps.
3. Using a clean, dry disposable wipe or paper towel, smooth each bead to press the sealant into the joint.
4. Remove the painter's tape immediately after smoothing each section.
5. Using a 3 mm hex wrench, fully tighten all enclosure screws that were loosened earlier.
6. Dampen a clean wipe with denatured alcohol and remove any residual sealant from the panel surfaces.
7. Cover the nozzle tip of the Sikaflex tube with painter's tape for future use.

Cure and Test

1. Allow the sealant to cure for 24 hours before moving the machine or operating flood coolant.
2. After 24 hours, run flood coolant and inspect all seams for leaks.
3. If any leaks are found:
 - Clean and dry the area completely.
 - Apply additional sealant as needed. Allow it to cure for an additional 24 hours, and then re-test for leaks.

Install the Air Gun

1. Unscrew the red ring from the regulator and install it onto the mounting bracket.
2. Connect the end of the airline without the T-fitting to the air in port on the regulator.

3. Install the mounting bracket with the regulator onto the machine stand using the two provided M6 screws. The mounting location is above the oiler.

 **Note:** Mounting holes are provided on both sides of the machine stand. You can mount the air gun on the right side if you prefer.

4. Secure the air line to the oil line using zip ties at regular intervals to keep them organized and prevent snagging.

 **WARNING!** Compressed Air: Ensure that the air compressor is turned off and the system is depressurized before disconnecting or connecting air lines. If you don't, the air pressure could cause the fittings to release forcefully, which could cause injury.

5. Identify the FRL (filter, regulator, lubricator) at the back of the machine. Disconnect the main air line from the air in port on the FRL.
6. Connect the short air line from the air gun's T-fitting to the air in port on the FRL.
7. Connect the main air line (the one you just disconnected) to the open port on the T-fitting.

 **Note:** You may choose to shorten the air lines now if there is excessive slack.

8. The holster mounts to the lower front enclosure panel using the same two M5 screws that secure the panel. Remove these two screws from the panel.
9. Position the holster over the mounting holes and reinstall the M5 screws through both the holster and the panel. Tighten securely.
10. Install the air gun nozzle onto the air gun body with a 1/2 in. wrench.
11. From the coiled air line, cut off the male quick-connect fitting with snips or a utility knife. Discard the removed fitting.
12. Connect the newly cut end of the air line to the output port on the air regulator.
13. Connect the loose end of the air line to the air gun itself.
14. Stow the air gun into its holster.

4.4.6 Install the Oiler

1. Find the hardware installed on the left side of the machine stand, as shown in the following image.

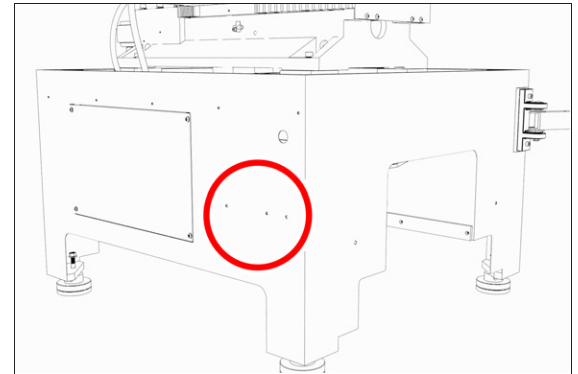


Figure 4-57: Oiler installation location on the left side of the machine stand.

2. Using the hardware from Step 1, attach the oiler to the machine stand with a 5 mm hex wrench.

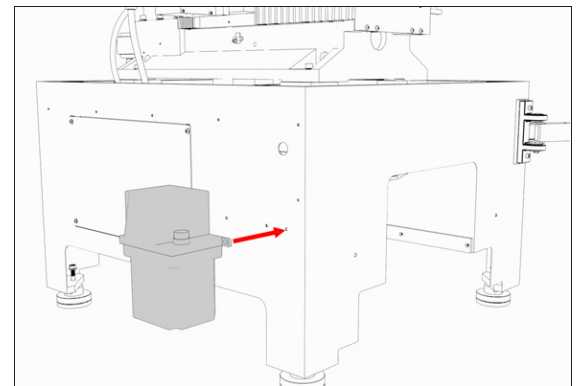


Figure 4-58: Automatic oiler installation on the machine stand.

1. Depending on your oiler type, do one of the following:
 - If you have an automatic oiler (strongly recommended), go to "Make Automatic Oiler Connections" (on the next page).
 - If you have a manual oiler, go to "Make Manual Oiler Connections" (on the next page).

 **Note:** You must confirm that the mill is regularly oiled. If you don't, there's a risk of motor faults. Use an Automatic Oiler Kit: 230 Vac (PN 38255).

4: INSTALLATION

4.4 Self-Assembled Installation

Make Automatic Oiler Connections

1. Connect the existing oil line on the mill to the oil line on the oiler.
2. Attach three mounting tabs to the machine stand with three M5 × 10 mm screws.
3. Route the power cord on the oiler to the back of the electrical cabinet, and connect it to any of the **Accessory** outlets.
4. Fill the oiler's sreservoir with machine oil to about 80% full.
1. You must verify the installation before you install any additional components. If you are not installing any additional components, you still must verify the core installation before you use the machine for the first time. Go to "Verify the Installation" (page 74).



Note: You'll set the interval time and the actuation time for the automatic oiler after you verify the core installation. For information, see "Set Up the Automatic Oiler" (page 78).

installation before you use the machine for the first time. Go to "Verify the Installation" (page 74).

Make Manual Oiler Connections

1. Remove and discard the orange plastic shipping plug from the oiler.
2. Connect the existing oil line on the mill to the oil line on the oiler.
3. Secure the oil line in the mounting clips on the machine stand.
4. Fill the oiler's sreservoir with machine oil to about 80% full.

Set Up the Manual Oiler

1. Pull and release the plunger on the oiler until oil is pushed through the distribution system. After that, pull the plunger at the following times:
 - Every time you power on the mill
 - Every four hours of operation
2. You must verify the installation before you install any additional components. If you are not installing any additional components, you still must verify the core

4.5 FACTORY-ASSEMBLED MACHINE SETUP

IMPORTANT! This section is for customers who purchased the machine **pre-assembled from the factory**. If you are assembling the machine yourself, many of the procedures that you'll need are not included in this section. Go to "Self-Assembled Installation" (page 49) for information specific to self-assembled machines.



Complete the following steps in the order listed:

4.5.1 Unpack the Machine Crate (Factory-Assembled).....	69
4.5.2 Connect the Air Gun	71
4.5.3 Connect the Coolant System.....	71
4.5.4 Mount the Operator Console.....	71
4.5.5 Set Up the Automatic Oiler.....	73

4.5.1 Unpack the Machine Crate (Factory-Assembled)



CAUTION! Sharp Objects Hazard: Before opening the shipping crate, you must put on work gloves and safety eyewear that meets ANSI Z87+. If you don't, the shipping crate and steel straps could cut you, causing serious injury.

1. Put on work gloves and eye protection.
2. Remove and discard the plastic packaging from the outside of the crate.
3. Remove the screws securing the top panel of the crate with a cordless drill and a Phillips bit. With a helper, lift the top panel off of the crate and set it aside.
4. With a helper, work your way around the crate, removing one panel at a time. Have your helper support the sides of the crate as you unscrew them.



Figure 4-59: Removing the side panels of the shipping crate.

5. Remove and discard the plastic bag from the outside of the machine.
6. Remove the PathPilot operator console box from the pallet and set it aside.
7. Remove the screws securing the coolant tank to the pallet with a cordless drill and a Phillips bit.



Figure 4-60: Removing the coolant tank's screws from the pallet.

8. With a helper, lift the coolant tank up and off of the pallet. We recommend setting the coolant tank onto a piece of cardboard to protect the paint.
9. Identify and remove the tool bag from the inside of the coolant tank. Inside the tool bag, identify the four casters, screws, and washers for the coolant tank.
10. Remove and set aside the chip tray. Then, stand the coolant tank on end to install the casters.

4: INSTALLATION

4.5 Factory-Assembled Machine Setup

11. Install the casters using four screws, washers, and a 6 mm hex wrench.



Figure 4-61: Installing the casters onto the coolant tank.

12. Tilt the coolant tank down onto its casters, reinstall the chip tray, and roll the coolant tank aside temporarily.
13. Remove the pallet from the machine: use a 14 mm socket to remove the six bolts securing the board on the right side of the pallet. Remove the board from the pallet.



Figure 4-62: Removing the bolts on the right side of the pallet.



Tip! You may need to use a dead-blow hammer to remove the board, because the weight of the pallet could make it difficult to slide out.

14. Remove the four bolts securing the machine to the pallet using a 19 mm socket and a ratchet.
15. Identify the four machine feet, M20 × 150 mm bolts, and washers from the tool bag. Install a nut and then a washer onto each foot.



Figure 4-63: Machine foot assembly.



WARNING! Lifting Hazard: Only use suitable lifting equipment, ensuring that it's on a stable, level surface. Never lift over people. Heavy loads could tip, fall, or shift unexpectedly, causing death or serious injury.

16. Carefully raise the machine up with a pallet jack from the right side of the machine. Slide the pallet out to the left of the machine.
17. With the machine still raised up on the pallet jack, thread the feet into each corner of the machine stand and tighten finger tight.
18. Adjust each foot so that the distance from the bottom of the machine stand to the bottom of the flat foot pad is 4 in. (10 cm). Then, tighten the nut finger tight against the washer.



Figure 4-64: Adjusting the height of the foot.

19. Slowly lower the pallet jack until the machine's four feet are completely on the floor.
20. With the machine on the floor, tighten the nut on each foot with an adjustable wrench.
21. Slide the coolant tank into the machine's stand.

4.5.2 Connect the Air Gun

1. From the tool bag, identify the air gun and its coiled hose.
2. Attach one end of the hose into the air gun, and stow the air gun onto the holster on the front of the machine's enclosure.



Figure 4-65: Stowing the air gun into the holster.

3. Route the loose end of the air gun's hose to the back of the machine, and connect it to the elbow fitting on the regulator.

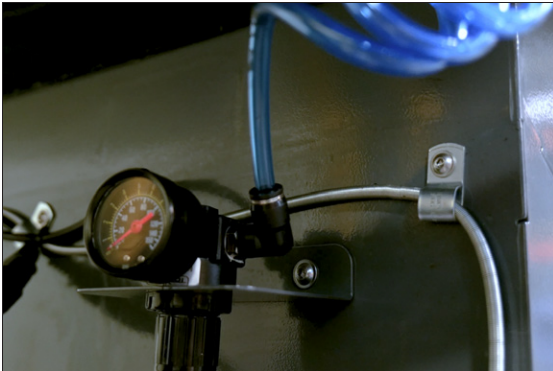


Figure 4-66: Air gun air line connected to the regulator.

4.5.3 Connect the Coolant System

1. From the tool bag, identify the coolant line, and attach it to the coolant pump.
2. Unravel the power cord for the coolant pump.
3. Route both the cord and the coolant line out the back of the coolant tank.
4. Connect the coolant line to the pre-installed hose at the back of the machine.
5. On the back of the machine, loosen the five screws securing the middle panel.

6. Slide the panel up and temporarily set it aside.
7. Route the power cord to the **Flood Coolant** outlet on the back of the machine.
8. Replace the panel that you set aside to make the connection.

4.5.4 Mount the Operator Console

1. Open the PathPilot operator console box and remove the operator console.
2. Install the two hinges onto the back of the operator console. The short side of each hinge attaches to the operator console.



Figure 4-67: Installing the hinges onto the operator console.



Note: The hinges are stiff and require bending to the proper angle. We recommend using an adjustable wrench to carefully bend each hinge to approximately 90 degrees before proceeding.

4: INSTALLATION

4.5 Factory-Assembled Machine Setup

3. With an assistant, lift the operator console and position it onto the console mount on the right side of the enclosure. One person should support the weight while the other aligns the hinges with the mounting holes. Secure the console to the mount.



Figure 4-68: Mounting the operator console onto the enclosure.

4. Route the loose end of the power, Ethernet, and emergency stop cables to the back of the enclosure. These cables route through the rectangular opening in the operator console mount and then up through the circular opening on the top of the mount. The operator console's power brick should rest on the inside ledge of the mount for support.



Figure 4-69: Routing the cables through the top operator console mount and to the top of the enclosure.

5. To route the jog pendant cable through the mount, you'll need to temporarily disassemble the DB25 connector: Remove the connector cover plate and set it aside.



Figure 4-70: Disassembling the jog pendant's DB25 connector.

6. Route the cable through the circular opening on the bottom of the mount.



Figure 4-71: Routing the jog pendant cable through the bottom of the operator console mount.

7. Reassemble the jog pendant's DB25 connector, and connect it to the back of the operator console.
8. Route the ATC USB cable from the back of the machine and through the openings on the operator console mount.
9. Bundle the cables inside the operator console mount together using zip ties.
10. Install the mouse panel onto the front of the operator console using two M4 screws. Place the keyboard and mouse onto the panels.
11. Install the jog shuttle panel onto the front of the operator console using two M4 screws. Place the jog pendant (which is magnetic) onto the panel.
12. Open the operator console's hinged front panel.

- Route the loose ends of the USB cables from the keyboard, mouse, and ATC into the operator console. Connect them to the USB ports on the controller.

Tip! If you have a hardwired Ethernet connection for network access (not required for machine operation), connect it to the LAN 2 port inside the operator console now.

- Close and secure the operator console's hinged front panel.
- Route the Emergency Stop cable, the Ethernet cable, and the operator console's power cable along the top of the enclosure and to the electrical cabinet.
- Connect the Emergency Stop cable to the **Emergency Stop** connector on the top of the electrical cabinet.
- Connect the Ethernet cable to the **Controller Communications** connector on the top of the electrical cabinet.
- Connect the operator console's power cord to the **Console Power** outlet on the side of the electrical cabinet.
- Bundle all of the cables on the top of the enclosure together, using zip ties at regular intervals to secure them neatly.

4.5.5 Set Up the Automatic Oiler

Complete the following steps in the order listed:

Specify the Interval Time	73
Specify the Actuation Time	73

Specify the Interval Time

The oiler distributes oil at the following times:

- When the machine is powered on
- After a specified interval

The interval time is the amount of time, in minutes, that the oiler waits between oil applications.

Note: If your machine will be unused for a long period of time (like overnight), we recommend powering off the machine to avoid over-lubricating the system.

- On the oiler's control panel, push and hold either of the **Minutes Adjustment** buttons. It doesn't matter which

button you push.

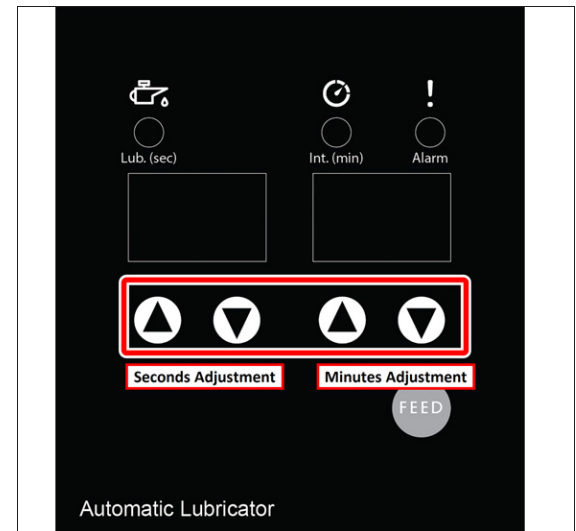


Figure 4-72: Automatic oiler control panel.

The oiler beeps.

- While looking at the **Minutes** display, do one of the following:
 - To increase the interval time, push the **Up Arrow**.
 - To decrease the interval time, push the **Down Arrow**.

NOTICE! Pressure Hazard: To avoid potential equipment damage, don't set the interval time to less than five minutes.

Specify the Actuation Time

The actuation time is the amount of time, in seconds, that the oiler distributes oil during an oil application.

- On the oiler's control panel, push and hold either of the **Seconds Adjustment** buttons. It doesn't matter which button you push. The oiler beeps.
- While looking at the **Seconds** display, do one of the following:
 - To increase the interval time, push the **Up Arrow**.
 - To decrease the interval time, push the **Down Arrow**.

NOTICE! Pressure Hazard: To avoid potential equipment damage, don't set the actuation time to more than three minutes.

4: INSTALLATION

4.6 Verify the Installation

4.6 VERIFY THE INSTALLATION

To properly validate the core installation of your machine, you must understand how to power on and off the machine and use the controls.

Complete the following steps in the order listed:

4.6.1 Power on the Machine	74
4.6.2 Verify Axes Function	75
4.6.3 Verify Spindle Function	76
4.6.4 Power off the Machine	77

4.6.1 Power on the Machine

1. Use a multimeter to verify that the electrical service in your location meets the following requirements. If your location does not meet these requirements, do not install the machine. Instead, you must consult with a local electrician about your options.
 - **Primary Power Required** Single-Phase 230 Vac, 50/60 Hz
 - **Recommended Circuit Amperage** Dedicated 20 A breaker
2. Connect the machine's mains power cable to the verified electrical service.
3. Find the Main Disconnect switch, and then remove the hang tag.

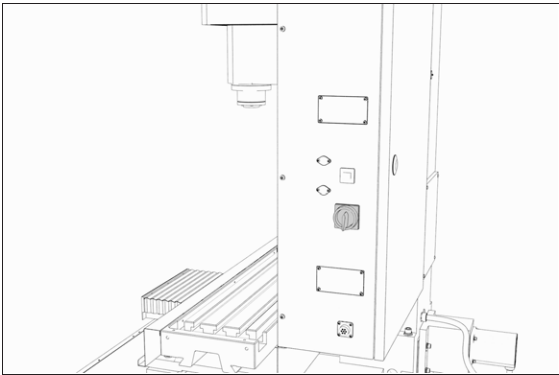


Figure 4-73: The Main Disconnect switch on the side of the machine's electrical cabinet.

4. Turn the Main Disconnect switch to **ON**.

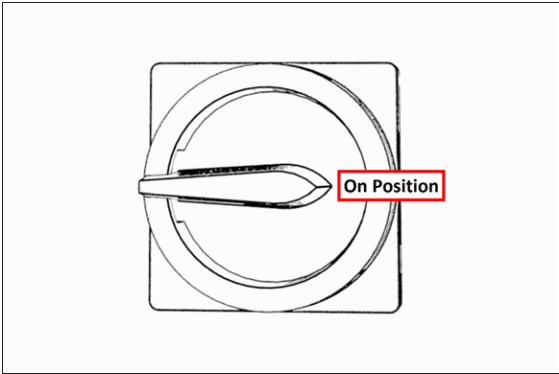
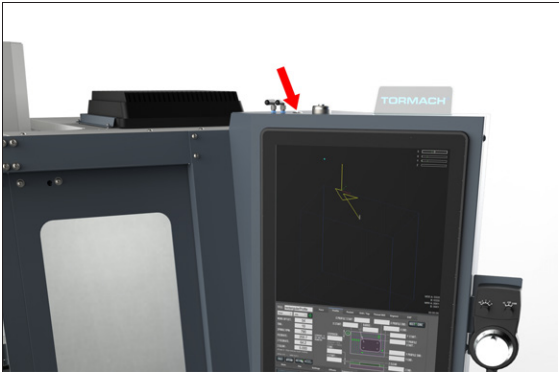


Figure 4-74: Example of the Main Disconnect switch in the On position.

Mains power is now connected to the machine.

5. Push the Power button on the PathPilot controller, if it's not already powered on.



6. Follow the on-screen instructions to configure the PathPilot operating system and PathPilot controller. When configuration is complete, the PathPilot operating system launches.

Note: After you first configure PathPilot, the operating system automatically launches whenever it's powered on.

7. Rotate the Emergency Stop button one-quarter turn clockwise to release it.



Figure 4-75: Emergency Stop button.

8. Push the blue Reset button to enable the machine.



Figure 4-76: Reset button.

The axis drives are now powered on.

9. Verify that the blue Reset LED comes on. From the PathPilot interface, on the **Status** tab, verify that the **Machine OK** light changes from yellow to green. Once both are on, the machine is powered on and ready to operate.

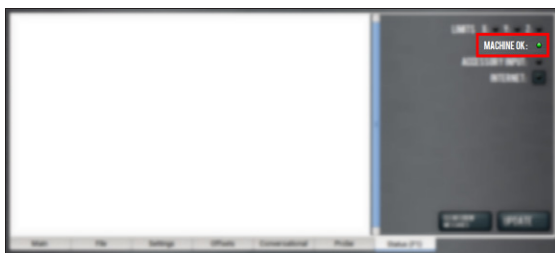


Figure 4-77: Machine OK light on the Status tab.

10. Select **Reset**.



Figure 4-78: Reset button.

This initializes the connection between the machine and controller.

4.6.2 Verify Axes Function

You must confirm that the axes correctly operate.

1. Select the **Page Up** key on the keyboard to move the spindle head up (Z+).
2. Remove and discard the shipping block from the machine table.
3. Reference the axes: from the PathPilot interface, select **Ref Z**, **Ref X** and **Ref Y**.



Figure 4-79: Ref Z, Ref X, and Ref Y buttons.

The machine moves to the reference position.

4. Use the keyboard to verify axes motion:
 - Select the **Right Arrow** key and then the **Left Arrow** key.
The table moves left (X+), then right (X-).
 - Select the **Down Arrow** key and then the **Up Arrow** key.
The table moves away from you (Y-), then toward you (Y+).
 - Select the **Page Down** key and then the **Page Up** key.
The spindle head moves down (Z-), then up (Z+).

4: INSTALLATION

4.6 Verify the Installation

5. If applicable, verify the optional Jog Shuttle:
 - Press any axis button on the Jog Shuttle — **X**, **Y**, **Z**, or **A** — to select an axis.

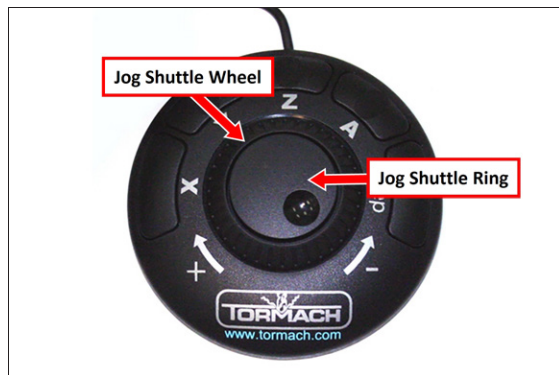


Figure 4-80: Functions on the optional Jog Shuttle.

From the PathPilot interface, on the **Main** tab, the corresponding green **Axis** light comes on.

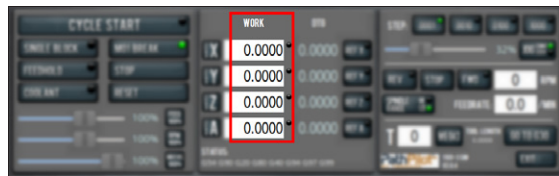


Figure 4-81: Axis lights.

- Turn the **Jog Shuttle Ring** in any direction to move the selected axis, then turn it in the opposite direction to reverse the direction.

4.6.3 Verify Spindle Function

You must confirm that the spindle correctly operates.

1. Open the spindle door and locate the spindle belt.
2. From the PathPilot interface, confirm that the **Spindle Range** button matches the spindle belt position.



Figure 4-82: Spindle Range button.

If necessary, select **Spindle Range** to match the spindle's belt position.

3. Close and latch the spindle door.
4. From the PathPilot interface, confirm that the **Spindle Override** slider isn't set to 0% (when it's set to 0%, the slider is yellow). To clear the override, select **RPM 100%**.



Figure 4-83: Spindle Override slider.

Note: The **Spindle Override** slider changes the programmed spindle speed by a specific percentage. If it's set to 0%, the spindle won't move during the following steps in this procedure. For information, see "About Spindle Override" (page 156).

5. From the PathPilot interface, in the **RPM DRO** field, type 500. Then select the **Enter** key.

Note: If you have an operator console, confirm that the **RPM** knob isn't set to 0%. If it is, turn the **RPM** knob.

6. Select **FWD**.



Figure 4-84: Spindle controls.

The spindle rotates clockwise (viewed from above) at 500 rpm.

7. Select **STOP**.
The spindle stops rotating.
8. Select **REV**.
The spindle rotates counterclockwise (viewed from above) at 500 rpm.
9. Select **STOP**.
The spindle stops rotating.
10. In the **RPM DRO** field, type 1000. Then select the **Enter** key.
11. Select **FWD**.
The spindle rotates clockwise (viewed from above) at 1000 rpm.
12. Repeat the procedure at 1000 rpm.

4.6.4 Power off the Machine

1. Push the Emergency Stop button to lock it into the disabled position.



Figure 4-85: Emergency Stop button.

With the Emergency Stop button in the disabled position all motion and spindle function stops, the Reset button is disabled, and the blue Reset LED goes off. From the PathPilot interface, on the **Status** tab, the **Machine OK** light illuminates yellow.

2. From the PathPilot interface, select **Exit**.
3. When prompted, select **OK**.
4. Once the PathPilot interface indicates that it's safe to power off the machine, turn the Main Disconnect switch to **OFF**.

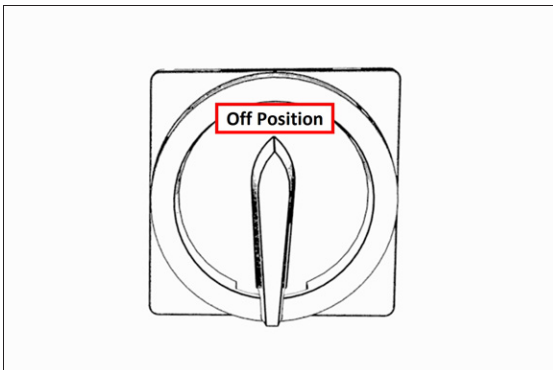


Figure 4-86: Example of the Main Disconnect switch in the Off position.

Mains power is disconnected from the machine.

4: INSTALLATION

4.7 Install Accessory Components

4.7 INSTALL ACCESSORY COMPONENTS

Install accessory components in the order specified, skipping any components that you don't have. Otherwise, you may need to remove an item in order to install another one. For example, if you install the Full Enclosure Kit, you must remove it in order to install any other component. When you're finished installing accessory components, go to "Set Up the PathPilot Controller" (page 99).

4.7.1 Set Up the Automatic Oiler.....	78
4.7.2 Install the Automatic Tool Changer (ATC).....	78
4.7.3 Install the Flood Coolant Kit.....	87
4.7.4 Install the 4th Axis.....	88
4.7.5 Install the Probe and Tool Setter.....	91

4.7.1 Set Up the Automatic Oiler

Complete the following steps in the order listed:

Specify the Interval Time.....	78
Specify the Actuation Time.....	78

Specify the Interval Time

The oiler distributes oil at the following times:

- When the machine is powered on
- After a specified interval

The interval time is the amount of time, in minutes, that the oiler waits between oil applications.

 **Note:** If your machine will be unused for a long period of time (like overnight), we recommend powering off the machine to avoid over-lubricating the system.

1. On the oiler's control panel, push and hold either of the **Minutes Adjustment** buttons. It doesn't matter which button you push.

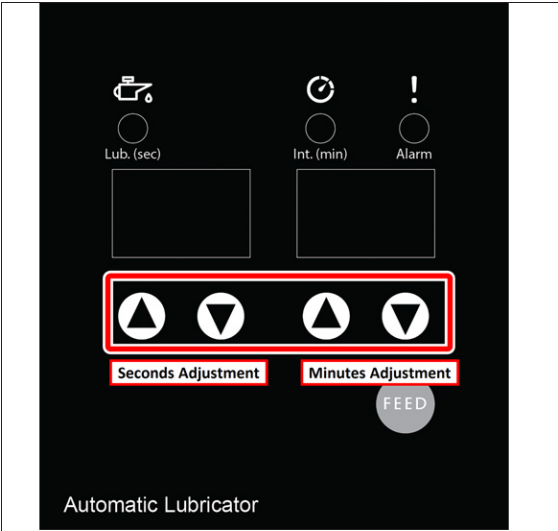


Figure 4-87: Automatic oiler control panel.

The oiler beeps.

2. While looking at the **Minutes** display, do one of the following:
 - To increase the interval time, push the **Up Arrow**.
 - To decrease the interval time, push the **Down Arrow**.

NOTICE! Pressure Hazard: To avoid potential equipment damage, don't set the interval time to less than five minutes.

Specify the Actuation Time

The actuation time is the amount of time, in seconds, that the oiler distributes oil during an oil application.

1. On the oiler's control panel, push and hold either of the **Seconds Adjustment** buttons. It doesn't matter which button you push.
The oiler beeps.
2. While looking at the **Seconds** display, do one of the following:
 - To increase the interval time, push the **Up Arrow**.
 - To decrease the interval time, push the **Down Arrow**.

NOTICE! Pressure Hazard: To avoid potential equipment damage, don't set the actuation time to more than three minutes.

4.7.2 Install the Automatic Tool Changer (ATC)

Complete the following steps in the order listed:

Required Tools.....	79
Air Requirements.....	79
Mount the Automatic Tool Changer (ATC) Bracket.....	79
Install the Main Assembly.....	80
Install the Air Cylinder.....	80
Make Air Connections.....	81
Make Electrical Connections.....	81
Verify the Installation.....	81
Level the Automatic Tool Changer (ATC).....	82
Alignment.....	85

Required Tools

This procedure requires the following tools. Collect them before you begin.

Required Tools for Installation

- 1-1/2 in. adjustable wrench
- 16 mm and 19 mm open-ended wrench
- FRL Filter-Regulator-Lubricator (PN 38829)
- Marker
- Metric hex wrench set
- Phillips screwdriver
- Small, flat-head screwdriver
- Snips
- Socket wrench, 13 mm socket, and (optionally) an extender

Required Tools for Verification

- BT30 tool holder (for alignment rod)
- Machinist's square, between 6 in. and 9 in. (152 mm and 229 mm)
- Straight rod (for BT30 tool holder), between 8 in. and 12 in. (203 mm and 305 mm)

Air Requirements

You must verify that the site conforms to the following air supply requirements.

- **Air Pressure** 90-120 psi (620-825 kPa)
If the air supply is more than 120 psi (825 kPa), you must use a regulator.
- **Air Volume** For successive, back-to-back tool changes, at least 2 cfm at 90 psi is required.
Exact air volume depends on the frequency of tool changes.

- **Dry Air** We recommend using a compressed air dryer, desiccator, or filter between the air compressor and the machine.
- **Lubricated Air** You must lubricate the air with air tool oil.
Use the pre-installed FRL Filter-Regulator-Lubricator for this purpose.

Mount the Automatic Tool Changer (ATC) Bracket

1. Identify the four provided standoffs that are used to mount the ATC to the Z-column:
 - Three fixed standoffs
 - One tilt standoff
2. Remove the flange nuts and the washers from the standoffs, and then set them aside.
3. Identify and remove the four set screws on the Z-column with a flat-blade screwdriver.
4. Install the four standoffs on the Z-column as shown in the following image.

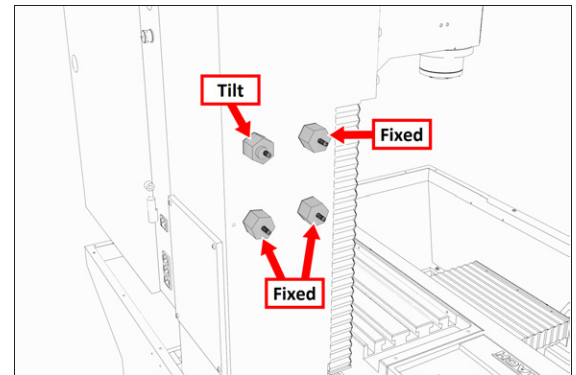


Figure 4-88: Four standoffs installed on the Z-column.

5. Securely tighten the standoffs on the Z-column with a 1-1/2 in. adjustable wrench.

4: INSTALLATION

4.7 Install Accessory Components

- Put the ATC mounting bracket on the standoff's threaded studs as shown in the following image.

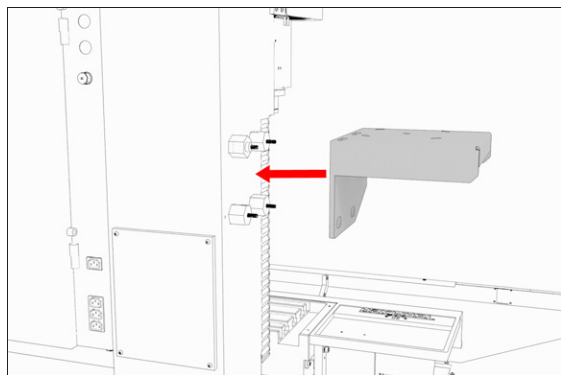


Figure 4-89: ATC mounting bracket moving on to the four standoffs.



Note: Verify that the tilt standoff's eccentric cam fits into the large slot on the ATC mounting bracket.

- Secure the bracket by reinstalling the washers and flange nuts that you removed in Step 2 with a 13 mm socket.
- Pull the bracket toward the front of the machine. You'll make adjustments to the location of the bracket later in this procedure, but we recommend starting with it moved forward.

Install the Main Assembly

- Remove the four preinstalled M8 × 1.25 - 16 mm socket head cap screws and washers from the bottom of the ATC electrical cabinet. Then, set all aside for later use.



CAUTION! Team Lift Required: You must have the aid of more than one person to lift and move the object. The object is heavy, and lifting it by yourself can cause serious injury.

- Lift the ATC main assembly on to the mounting bracket.

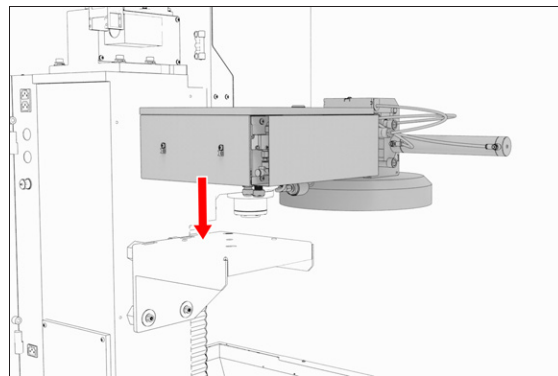


Figure 4-90: ATC main assembly positioned above the mounting bracket.

- Align the locating pin on the ATC main assembly with the matching hole in the mounting bracket.
- Secure the ATC main assembly to the mounting bracket with the four M8 × 1.25 - 16 mm socket head cap screws and washers that you set aside in Step 1.

Install the Air Cylinder

- Attach the air cylinder on to the ATC main assembly.

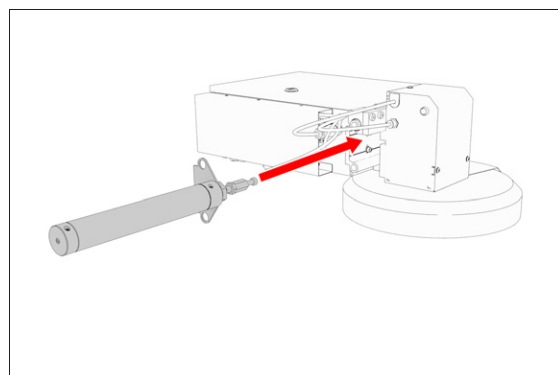


Figure 4-91: Putting the air cylinder into the ATC main assembly.

2. Secure the air cylinder to the ATC main assembly with a 12 mm hex wrench (provided) and two M14 × 20 mm socket head cap screws.

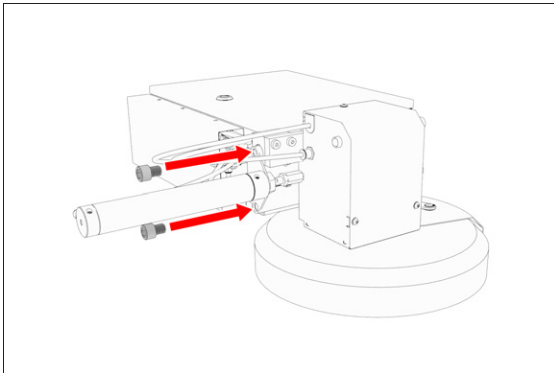


Figure 4-92: Putting the air cylinder hardware into the air cylinder.

3. Connect the air lines from the ATC main assembly to the air cylinder as follows:
 - Connect the short air line to the front of the cylinder.
 - Connect the long air line to the back of the cylinder.

Make Air Connections

1. Cut the cable tie that secures the ATC cables and plastic tubes together with snips.
2. Route the loose ends of the two 1/4 in. plastic tubes connected to the ATC main assembly through the enclosure knockout, up the energy chain, and toward the Power Drawbar. Then, pull the air line from the FRL back through the energy chain.

⚠ WARNING! Crush Hazard: If the ATC isn't completely retracted, it could move once the air is reconnected. When you reconnect the air, you must keep your hands away from the ATC.

3. Trim and connect the loose ends of the 1/4 in. plastic tubes in the following order:
 - a. Connect the Retract (PDB Bottom) airline to the bottom push-to-connect elbow on the Power Drawbar.
 - b. Connect the Advance (PDB Top) airline to the top push-to-connect elbow on the Power Drawbar
 - c. Connect the air supply line from the FRL to the air in port in the ATC main assembly, as shown in the following image.

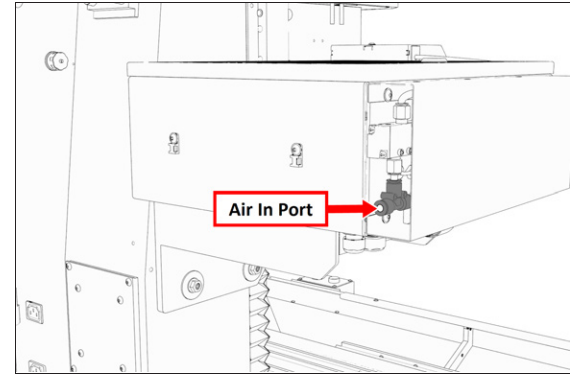


Figure 4-93: Air in port in the ATC main assembly.

- d. If you haven't already done so, connect your shop's air supply to the FRL.

Make Electrical Connections

1. Route the ATC power cable and the USB cable toward the rear of the machine and out of one of the enclosure knockouts.
2. Put the USB cable in the access hole in the rear of the stand toward the controller.
3. Put the USB cable into an open USB port on the PathPilot controller.

IMPORTANT! Do not connect the ATC USB cable to a USB hub. Make the connection directly to the PathPilot controller itself. If you don't have any free USB ports on the controller, connect a different accessory to a USB hub.

4. Connect the ATC power cable to the ATC Power connector on the side of the electrical cabinet (below the Enclosure Lights Power connectors).

Verify the Installation

1. Power on the machine and the PathPilot controller.
 - a. Turn the Main Disconnect switch to **ON** on the side of the electrical cabinet.
 - b. Twist out the machine's red Emergency Stop button, which enables movement to the machine axes and the spindle.
 - c. Press the machine's Reset button (next to the Emergency Stop button).
 - d. Bring the machine out of reset and reference it.

4: INSTALLATION
4.7 Install Accessory Components

IMPORTANT! You must update your controller to the latest version of PathPilot before operating the Automatic Tool Changer. If you don't, there's a risk that the ATC could become inoperable.

- 2. If you have not yet done so, you must make sure that the PathPilot controller is updated to the latest version of PathPilot: From the Status tab, select Update. Then, follow the on-screen instructions.
- 3. From the PathPilot interface, on the Settings tab, select the ATC radio button.

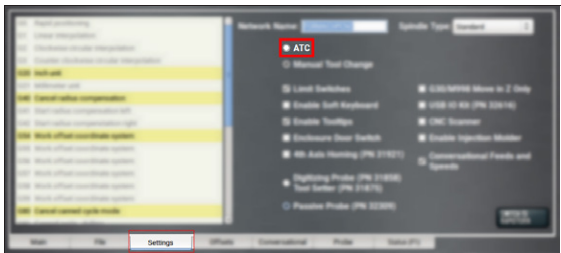


Figure 4-94: ATC radio button on the Settings tab.
The ATC tab appears in the PathPilot interface.

Note: If prompted, you may need to update the firmware for the ATC. Follow the on-screen instructions.

- 4. Load a tool into the spindle:
a. Push and hold the drawbar open button on the side of the ATC.



Figure 4-95: Drawbar open button on the side of the ATC.

The drawbar opens.

- b. Load a tool into the spindle.

- c. Release the button.
The drawbar closes.
- 5. From the PathPilot interface, on the Main tab, in the RPM DRO field, type 1000. Then select the Enter key.
- 6. Select FWD.
The spindle starts.
- 7. From the Status tab, make sure that the VFD Running green light comes on.



Figure 4-96: VFD Running light on the Status tab.

Note: If the VFD Running light did not come on in the previous step, we can help. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

- 8. Select Stop.
The spindle stops.

Level the Automatic Tool Changer (ATC)

This section gives instructions to roughly level the ATC on the machine by using a long, straight rod. More adjustments are made later in the installation procedure.

NOTICE! After the initial installation, you must level the ATC. If you don't, there's a risk of machine damage.

Complete the following steps in the order listed:

Prepare the Machine..... 83
Examine Perpendicularity in the Y Direction..... 83
Examine Perpendicularity in the X Direction..... 83
Examine the Alignment of the Carousel Door Opening... 84

Prepare the Machine

1. Push the tool tray toward the spindle.

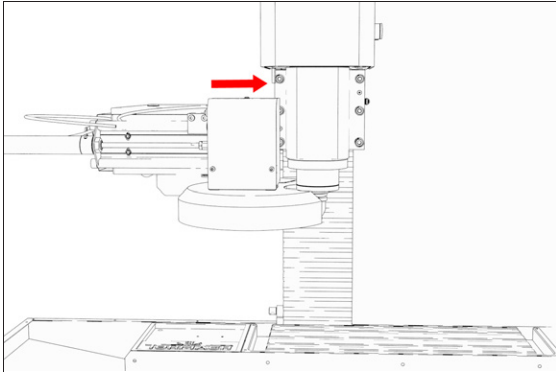


Figure 4-97: Tool tray moved in toward the spindle.

2. Verify that the linear bearing on the ATC is flush with the ATC main assembly.

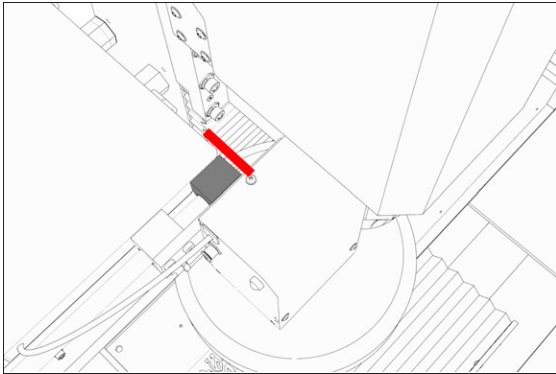


Figure 4-98: Linear bearing flush with the ATC main assembly.

3. Find a straight rod between 8 in. and 12 in. (203 mm and 305 mm) long. Verify that it's straight: roll it on a known flat surface (like a granite surface plate).



Note: You'll use the rod to verify that the ATC is correctly installed on the mill, so it must be straight.

4. Put the alignment rod into a tool holder.
5. Put the tool holder into the fork so that the groove in the tool holder slides into the fork, and so that the drive slot aligns with the dog. Don't rest the tool holder on top of the fork.
6. Put a machinist's square on the machine table.

Examine Perpendicularity in the Y Direction

1. Verify that the rod is perpendicular to the machine table in the Y direction: compare the rod's position to the vertical edge of the machinist's square.
 - If the rod is perpendicular to the vertical edge of the machinist's square, go to "Examine Perpendicularity in the X Direction" (below).
 - If the rod must be adjusted, go to Step 2.
2. Loosen the flange nuts on the standoffs.
3. Turn the tilt standoff with an adjustable wrench, and slowly pivot the ATC until the rod is perpendicular to the vertical edge of the machinist's square.

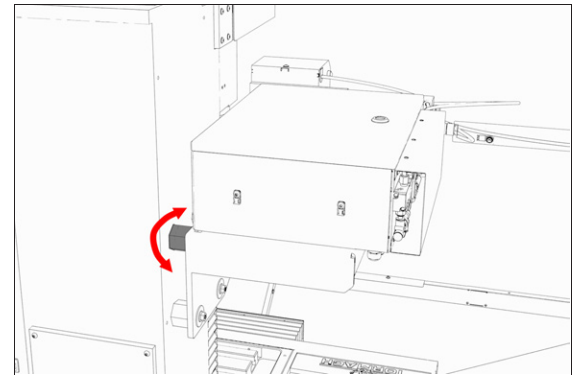


Figure 4-99: Tilt standoff.

4. Tighten the flange nuts with a 13 mm socket.
5. Reexamine the alignment of the ATC in the Y direction. If the rod isn't perpendicular to the vertical edge of the machinist's square, repeat Steps 2 through 5.

Examine Perpendicularity in the X Direction

1. Verify that the rod is perpendicular to the machine table in the X direction: compare the rod's position to the vertical edge of the machinist's square.
 - If the rod is perpendicular to the vertical edge of the machinist's square, go to "Examine the Alignment of the Carousel Door Opening" (on the next page).
 - If the rod must be adjusted, go to Step 2.

4: INSTALLATION

4.7 Install Accessory Components

2. Loosen the two socket head cap screws on the linear rails.

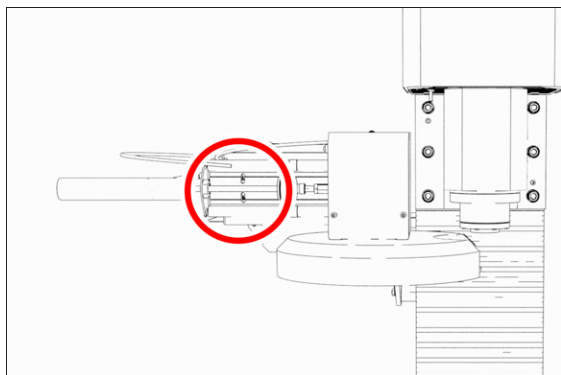


Figure 4-100: Socket head cap screws on the linear rails.

3. Slowly pivot the linear rails up or down until the rod is perpendicular to the vertical edge of the machinist's square.
4. Tighten the socket head cap screws.
5. Reexamine the alignment of the ATC in the X direction. If the rod isn't perpendicular to the vertical edge of the machinist's square, repeat Steps 2 through 5.

Examine the Alignment of the Carousel Door Opening

1. Remove the tool holder from the fork, and set it aside.



Note: You'll need this tool later in the installation procedure to make further alignments.

2. Power on the machine and the PathPilot controller.
 - a. Turn the Main Disconnect switch to **ON** on the side of the electrical cabinet.
 - b. Twist out the machine's red Emergency Stop button, which enables movement to the machine axes and the spindle.
 - c. Press the machine's Reset button (next to the Emergency Stop button).
 - d. Bring the machine out of reset and reference it.
3. Verify that the ATC is all the way forward (toward the spindle), and then slowly move the Z-axis down (-Z) to examine the clearance of the carousel door opening.
4. Verify that the carousel door opening is approximately equal to the front back and left of the spindle mounting flange:

- If the carousel door opening is approximately equal, go to Step 8.

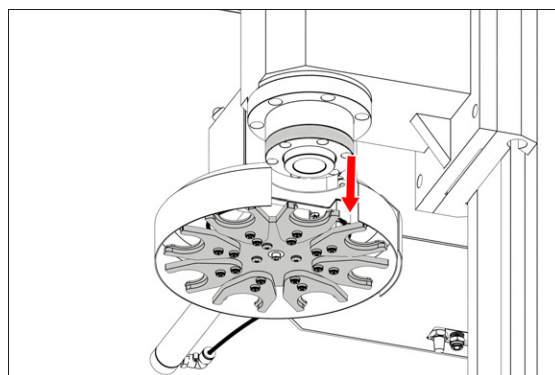


Figure 4-101: Distance between the carousel door opening and the spindle mounting flange.

- If the carousel door opening must be adjusted, go to Step 5.
5. Loosen the four socket head cap screws that secure the ATC main assembly to the mounting bracket with a 6 mm hex wrench.

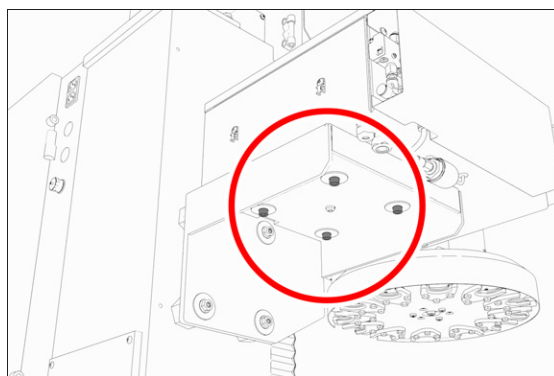


Figure 4-102: Socket head cap screws securing the ATC main assembly to the mounting bracket.

6. Adjust the carousel door opening as required:
 - **If the Carousel Door Opening is Contacting the Front** Pivot the ATC around the locating pin on the bottom of the mounting bracket toward the front of the machine (closer to you).
 - **If the Carousel Door Opening is Contacting the Back** Pivot the ATC around the locating pin on the bottom of the mounting bracket toward the back of the machine (closer to the machine column).
 - **If the Carousel Door Opening is Contacting the Left** Loosen the four flange nuts that attach the mounting bracket to the column to move the bracket forward or backward.



Note: Moving the ATC mounting bracket could change the position of the tilt standoff (on the Z-column). If you move it, you must verify that the ATC is still correctly installed; go to "Examine Perpendicularity in the Y Direction" (page 83).

Repeat this step as needed.

7. Tighten the socket head cap screws and the flange nuts (if you loosened them in Step 5).
8. Move the tool tray to its retracted position.
9. Center the machine table: from the PathPilot interface, in the **MDI Line DRO** field, type `G20 G53 G1 X7 Y-3.75 Z0 F20`. Then select the **Enter** key.
10. Power off the machine and the PathPilot controller.
 - a. Push in the machine's red Emergency Stop button, which removes power to motion control.
 - b. From the PathPilot interface, select **Exit**.
 - c. Turn the Main Disconnect switch to **OFF** on the side of the electrical cabinet.

Alignment

In this section, you'll adjust the tool alignment and set the tool tray height and encoder position.

1. From the PathPilot interface, on the **ATC** tab, select **Ref Tool Tray**.



Figure 4-103: Ref Tool Tray button on the ATC tab.

The tool tray spins.



Note: You're only required to reference the tool tray once, unlike the mill axes' referencing procedure.

2. If you haven't already done so, load a tool into the spindle.
3. Manually rotate the spindle two revolutions by hand. The encoder has now been oriented.
4. Disconnect the air from the machine.
5. While manually advancing the tool tray toward the spindle, align the fork with the tool. Complete the following steps in the order listed:
 - a. Slowly jog the Z-axis up or down until the groove in the fork aligns with the groove in the tool holder.
 - b. Determine if the tray must move clockwise or counterclockwise to align the fork with the tool holder. From the PathPilot interface, in the **ATC** tab, either select **--** to step the tool tray counterclockwise or **++** to step the tool tray clockwise.
 - c. Fully seat the ATC to its tray load position, verifying that the tool and its drive dog slots are fully inserted into the fork.
6. Verify that, from the **Status** tab, the **ATC Tray In** LED is still illuminated.
If the LED isn't illuminated, examine the tool tray. It may have exceeded the Tray In sensor during adjustments in the previous step.

4: INSTALLATION

4.7 Install Accessory Components

7. On the **ATC** tab, select **Set TC POS**.



Figure 4-104: Set TC POS button on the ATC tab.

The tool change position has now been set.

8. Select **Set TC M19**. Then, in the dialog box that displays, select **OK**.

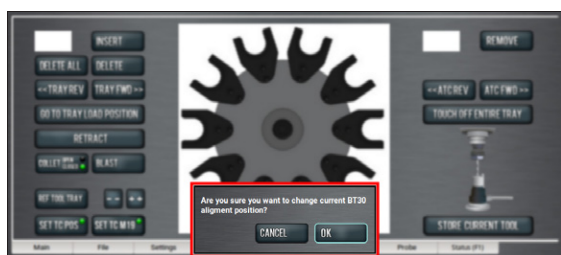


Figure 4-105: Confirmation dialog box to change the spindle's alignment position.

9. Follow the on-screen instructions to set the spindle's tool change rotation position:
- Rotate the spindle clockwise in the fork by hand. Then, select **OK**.
 - Rotate the spindle counterclockwise in the fork by hand. Then, select **OK**.
- The tool change rotation position has now been set. In the dialog box that displays, select **OK**.
10. Manually move the ATC back to the retracted position.



WARNING! Crush Hazard: If the ATC isn't completely retracted, it could move once the air is reconnected. When you reconnect the air, you must keep your hands away from the ATC.

11. Reconnect the air.
12. Remove the tool from the spindle.
13. Move the Z-axis up: in the **MDI Line DRO** field, type **G20 G53 G1 Z0 F20**. Then select the **Enter** key.
14. On the **ATC** tab, select **Go To Tray Load Position**. Then, manually load a tool into the fork.

15. Orient the spindle: from the PathPilot interface, in the **MDI Line DRO** field, type **M19 R0 Q10**. Then select the **Enter** key.

16. Open the drawbar: on the ATC tab, select **Collet**, and wait until the LED toggles from **Closed** to **Open**.



Note: You must verify that the drawbar is open (and not just that the brake is engaged) before you continue.

17. Verify that the spindle is concentric with the tool: slowly jog the Z-axis down and, depending on the result, do one of the following:

- **If the Spindle is Concentric with the Tool** You've completed the alignments.
- **If Adjustments are Required** Go to Step 18.

18. Determine if the tray must move left or right. Use two wrenches to loosen the jam nut on the end of the cylinder rod, making sure that you don't spin the rod end when adjusting the jam nut. Then, either turn the rod end one-half turn further on to the cylinder rod to move the tool tray to the left, or turn it one-half turn off of the cylinder rod to move the tool tray to the right. Once finished, tighten the jam nut.

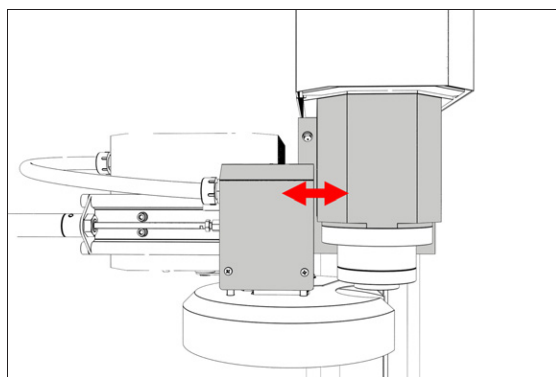


Figure 4-106: Moving the tool tray left or right.



Note: Don't move the tool tray more than 0.100 in. in either direction (left or right). If you do, the tool tray will exceed the Tray In sensor, which affects how ATC operations are communicated to PathPilot.

19. Adjust for the ATC's backlash: apply light pressure forward and backward on the carousel; then, from the PathPilot interface, on the **ATC** tab, select ++ or -- until there's equal space on the front and the back of the BT30 taper.
20. Verify that, from the **Status** tab, the **ATC Tray In** LED is still illuminated.
If the LED isn't illuminated, examine the tool tray. It may have exceeded the Tray In sensor during adjustments in the previous step.
21. Repeat adjustments until the tool's shank is concentric with the spindle.
22. Move the Z-axis up: in the **MDI Line** DRO field, type G20 G53 G1 Z0 F20. Then select the **Enter** key.
23. Remove the tool from the ATC. Then, select **Retract**.

4.7.3 Install the Flood Coolant Kit

Complete the following steps in the order listed:

- Adjust the Coolant Pump Motor Strapping** 87
- Set Up the Flood Coolant Kit** 87

Adjust the Coolant Pump Motor Strapping

Because the coolant pump is dual voltage, you may need to adjust the motor strapping.

1. Identify the jumper configuration diagram. The coolant pump motor strapping varies by machine:
 - **1100M, 1100MX, 770MX (ML)** 220 Vac (high volt)
 - **770M, 770MX (MF)** 120 Vac (low volt)



Figure 4-107: Coolant pump motor jumper configuration diagram.

2. Remove the access cover on the coolant pump.
3. Reference the configuration diagram and move the jumper to the 220 Vac (high volt) position. Don't change the position of any wires – just the jumper that connects

the terminals.

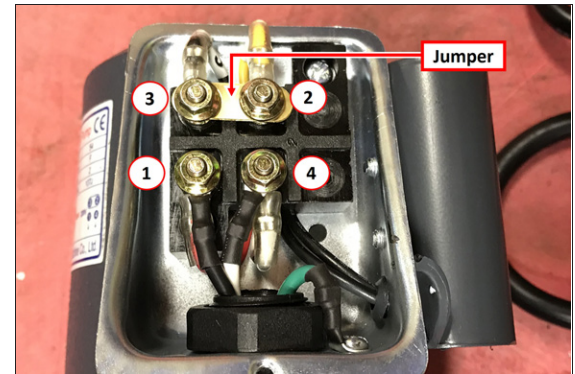


Figure 4-108: Coolant pump motor strapping adjusted for 220 Vac.

4. Reinstall the access cover on the coolant pump.

Set Up the Flood Coolant Kit

1. Attach the threaded elbow into the pump with a 22 mm open-ended wrench. Twist the elbow so that it's pointing up.
2. Attach the coolant pump to the coolant tank with the four M6 × 1 - 22 screws provided.

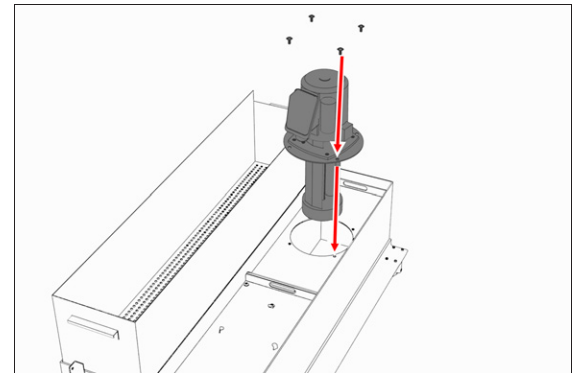


Figure 4-109: Coolant pump and its hardware moving into the coolant tank.

4: INSTALLATION

4.7 Install Accessory Components

3. Remove the coolant hose bracket from the rear of the Machine Stand. Set the hardware aside.

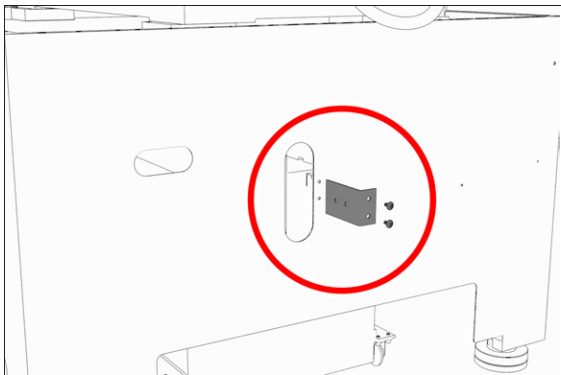


Figure 4-110: Coolant hose bracket and its hardware removed from the Machine Stand.

4. Attach the provided Y-fitting to the coolant hose bracket, and then install the coolant hose bracket back on the Machine Stand using the hardware that you set aside in Step 4.
5. Identify the two provided coolant hoses: the self-retracting coolant hose and the long coolant hose.
6. Put the self-retracting coolant hose into the top of the Y-fitting.
7. Put the provided plug into the remaining side of the Y-fitting.
8. Cut a 3 in. (76 mm) piece of the longer coolant hose with snips.
9. Put the newly cut piece of the coolant hose into the bottom of the Y-fitting. Then, put the provided elbow onto the its loose end.
10. Put the remainder of the long coolant hose into the open end of the elbow.
11. Route the loose end of the long coolant hose through the Machine Stand, through the energy chain, and to the spindle head.
12. Attach the coolant manifold to the spindle nose with the two screws provided.

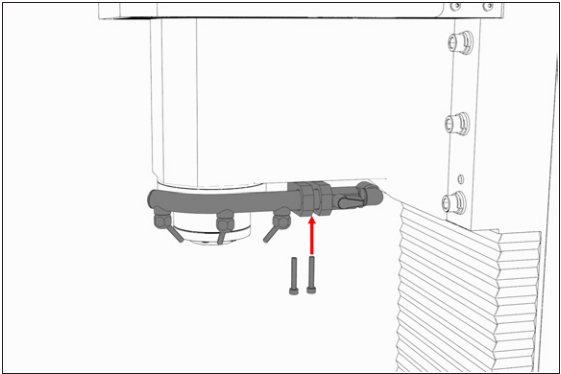


Figure 4-111: Attaching the coolant manifold to the spindle nose.

13. Put the loose end of the long coolant hose into the coolant manifold.
14. Route the loose end of the self-retracting coolant hose through the rear of the Machine Stand, and then put it into the elbow on the coolant pump.
15. Move the coolant tank into the Machine Stand.
16. Route the power cord on the coolant pump to the rear of the electrical cabinet, and connect it to the Coolant Pump Power outlet.
17. Verify that the coolant setup operates properly:
- a. From the PathPilot interface, on the **Main** tab, select **Coolant**.
The coolant pump powers on.
 - b. Select **Coolant** again.
The coolant pump powers off.
18. Secure coolant tank's front panel to the Machine Stand with the two provided M8 × 1.25 – 16 flanged button head cap screws. Adjust the front panel alignment as necessary using the six mounting screws securing the front panel to the coolant tank.

4.7.4 Install the 4th Axis

Complete the following steps in the order listed:

Set Up the microARC 4	88
Verify the Installation	90

Set Up the microARC 4

Complete the following steps in the order listed:

Required Tools	89
Install in Machine	89
Center the Chuck Mounting Plate	90

Required Tools

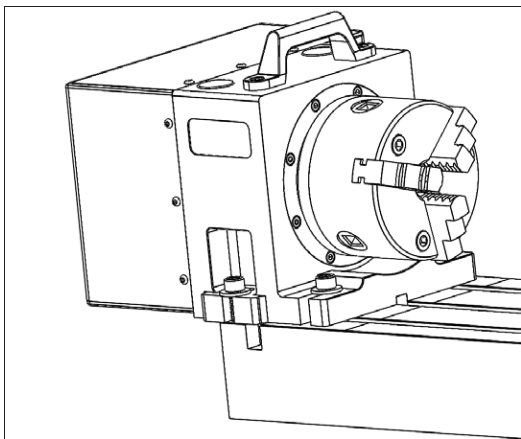
This procedure requires the following tools. Collect them before you begin.

- 3 mm hex wrench
- Dead-blow hammer (or similar)
- Magnetic dial indicator

Install in Machine

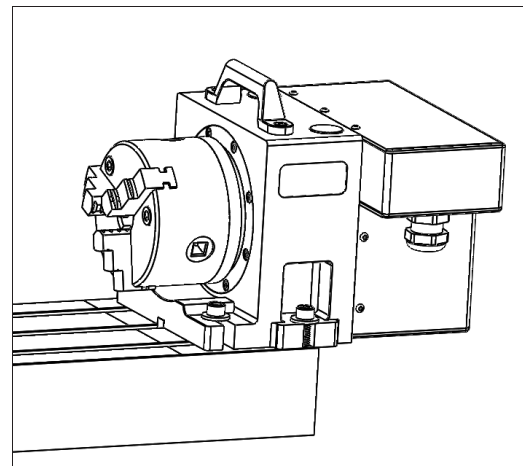
NOTICE! Before connecting or disconnecting the A-axis motor cable, you must push in the machine's red Emergency Stop button and power off the machine. If you don't, you may cause property damage or void your warranty replacement.

1. Power off the machine and the PathPilot controller.
 - a. Push in the machine's red Emergency Stop button, which removes power to motion control.
 - b. From the PathPilot interface, select **Exit**.
 - c. Turn the Main Disconnect switch to **OFF** on the side of the electrical cabinet.
2. Put the microARC 4 on the machine table. There are several mounting configurations available, depending on the particular needs of a given project:
 - a. **Left Side (Using Accessory Mounting Holes)** This configuration provides the maximum available X work space. If used with an ATC, the available tool clearance is 10 cm from TTS flange to tool tip with the 4th axis carrying handle removed.



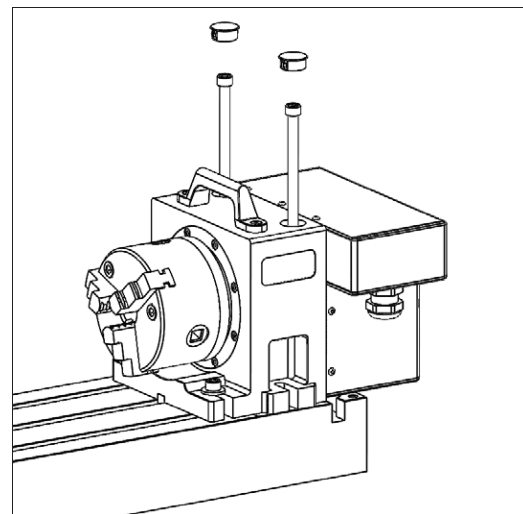
- b. **Right Side (Using Accessory Mounting Holes)**
Using the 4th axis on the far right side of the machine table provides the most X work envelope, but

interferes with the right side enclosure window, if installed.



- c. **Right Side (Using 6" Through-Bolts into T-Slots)**

X work envelope is reduced in this configuration, but it provides clearance for long tooling in the ATC.



3. Feed the motor cable under the electrical cabinet and plug it into the 7-pin connector you installed with the driver kit.
4. Loosely install the 5/16" mounting bolts, using either the threaded accessory mounting holes on your machine table or T-nuts.
5. Use the key on the bottom of the 4th axis to perform a rough alignment of the unit to the T-slots in your machine's table. If you need to perform a precise alignment, put a straight test bar into the chuck and sweep along it in X with an indicator. Adjust the orientation of the 4th axis until the reading does not deviate during the sweep.

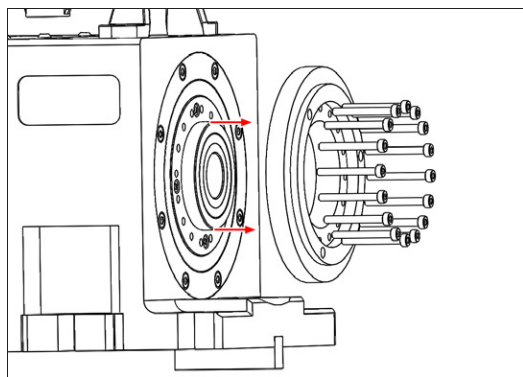
4: INSTALLATION

4.7 Install Accessory Components

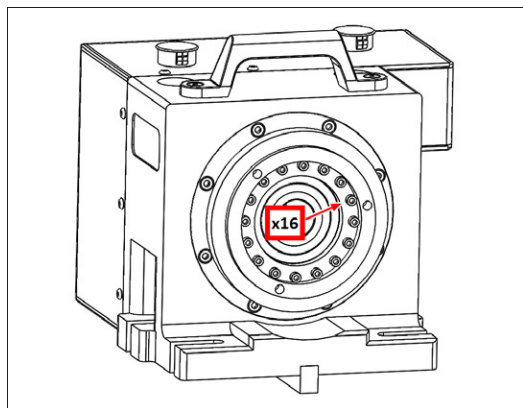
6. Tighten the mounting hardware with a hex wrench.

Center the Chuck Mounting Plate

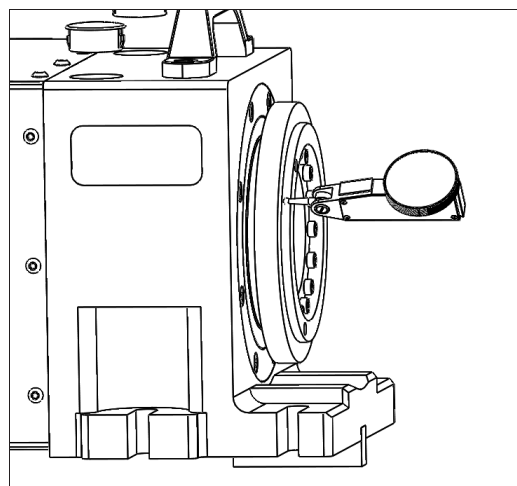
1. Remove the chuck from the 4th axis, if installed.
2. From the PathPilot interface, verify that you can rotate the 4th axis with either the jog keys on the keyboard or the jog shuttle.
3. The mounting plate is designed for a loose fit onto the output of the harmonic drive. This allows you to adjust the center of rotation to control runout at the chuck.



4. Slightly loosen the 16 M3 button head cap screws that hold the chuck mounting plate to the output of the harmonic drive. They should still be snug enough that the mounting plate is held in place by friction but can be nudged with a dead-blow hammer.



5. Put a tip of a dial test indicator on the mounting flange for the chuck.



6. Using PathPilot, jog the 4th axis 360 degrees, noting the spot where the indicator is highest.
7. Using the dead-blow hammer, gently tap the highest indicated spot towards the center and repeat the 360 degree sweep. Continue adjusting the high spot towards the center of rotation and sweeping until you reach your desired runout.
8. Tighten the 16 M3 mounting screws by hand to 1.1 Nm.
9. Reinstall the chuck or ER-40 collet holder.

Verify the Installation

1. Make sure that all wires on the motor driver and the DC-BUS board are completely connected.
2. Replace the wire trough covers.
3. Connect the rotary table to the A-Axis Encoder connector on the side of the electrical cabinet.
4. Power on the machine and the PathPilot controller.
 - a. Turn the Main Disconnect switch to **ON** on the side of the electrical cabinet.
 - b. Twist out the machine's red Emergency Stop button, which enables movement to the machine axes and the spindle.
 - c. Press the machine's Reset button (next to the Emergency Stop button).
 - d. Bring the machine out of reset and reference it.

5. From the PathPilot interface, test the movement of the rotary table:
 - Press **COMMA** on the keyboard to jog the rotary table in the -A direction.
 - Press **PERIOD** on the keyboard to jog the rotary table in the +A direction.

4.7.5 Install the Probe and Tool Setter

Complete the following steps in the order listed:

Before You Begin	91
Required Tools.....	91
Notes.....	91
Wireless Receiver Installation	91
Tool Setter Installation and Setup	93
Align the Tool Setter's Stylus.....	93
Reference the Tool Setter.....	94
Set G37 Position.....	95
Wireless Probe Installation and Setup	95
Adjust Probe Tip Concentricity.....	96
Set Probe Length and Diameter.....	96
Probe Status Lights Reference.....	98

Before You Begin

Make sure that:

- The machine is powered on.
- The enclosure is installed.

Required Tools

- 1-2-3 block
- Metric hex wrench set
- Dial test indicator (0.0005 in. indicator or better) with magnetic base
- Flat-blade screwdriver

Notes

- Torque fasteners to the noted specification. If no specification is noted, hand tight is sufficient.

Wireless Receiver Installation

1. Identify the wireless receiver, bracket, cable, and hardware included in this kit.



Figure 4-112: Wireless receiver kit contents.

Note: The provided remote can be used for programming, but the receiver is already programmed. If you need assistance with programming the receiver, contact tech support.

2. You can install the wireless receiver into the enclosure in either of the following ways:
 - a. Use the provided bracket to mount the receiver to the enclosure panel. With this installation method, you're able to better position the receiver toward the spindle.
 - b. The receiver is magnetic, so you can just place it onto the enclosure. With this installation method, you have more flexibility in the placement of the receiver.

4: INSTALLATION

4.7 Install Accessory Components

3. To mount the receiver with the provided bracket on the enclosure panel, first attach the bracket to the screw hole nearest to the enclosure door on the inside of the front right enclosure panel (behind the operator console) using the included hardware and a 4 mm hex wrench.

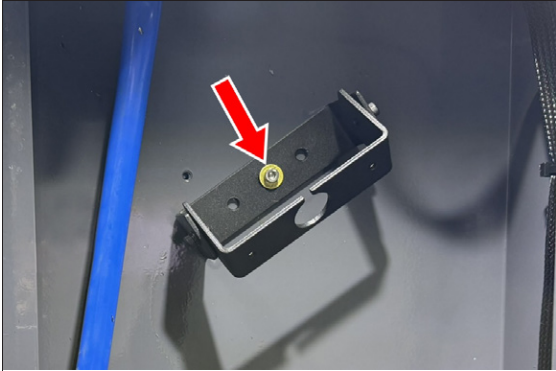


Figure 4-113: Bracket installed on the inside of the enclosure panel.

Note: There are two hole patterns available.



You can use either of them to make sure that the probe has a good connection.

4. Attach the wireless receiver to the bracket using the included hardware and a 4 mm hex wrench.

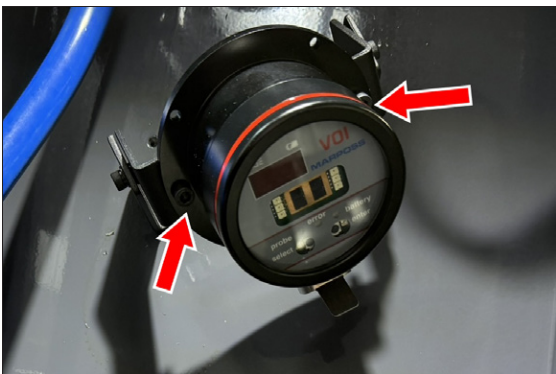


Figure 4-114: Wireless receiver mounted to the bracket.

5. Align the pin on the cable with the pin on the receiver. Connect the cable to the receiver, and lower bracket to secure it in place.



Figure 4-115: Cable connected to the wireless receiver.

6. Adjust the wireless receiver's bracket to point the receiver's panel towards the mill's spindle.
7. Remove the grommet on the top of the enclosure, and slide it onto the loose end of the wireless receiver's cable. Reinstall the grommet back onto the top panel of the enclosure, and pull the slack through.
8. Route the wireless receiver's cable back towards the mill's electrical cabinet.

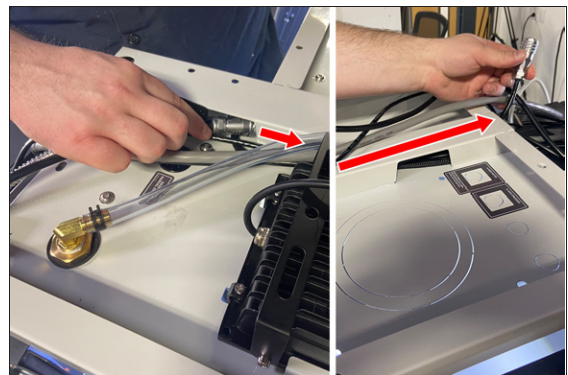


Figure 4-116: Wireless receiver's cable routing through the top panel on the enclosure.

9. Connect the wireless receiver's cable to the **Probe Control** connector on the bottom of the mill's electrical cabinet. Align the red dots on both the cable and the connector.



Figure 4-117: Red dot on the cable to align with the red dot on the connector.

10. Secure the wireless receiver's cable using zip ties.



Figure 4-118: Cable connection made and secured with Velcro cable ties.

Tool Setter Installation and Setup

1. Identify the electronic tool setter included in this kit. Remove the base off of the tool setter with a 4 mm hex wrench.



Figure 4-119: Base removed from the tool setter.

2. Install the tool setter's base ring to the machine table with the provided M12 × 1.75 - 30 socket head cap screw.

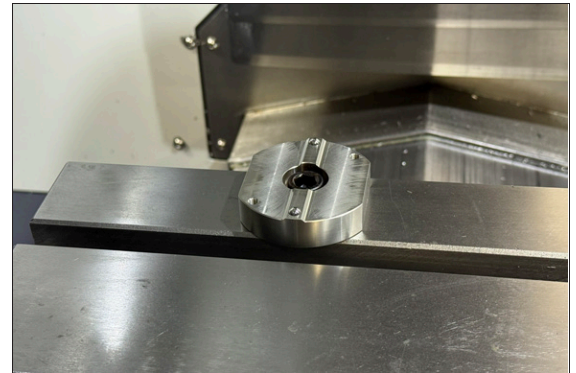


Figure 4-120: Base ring installed on the machine table.

3. Place the tool setter assembly over the base ring and secure it to the base ring by tightening the set screws.

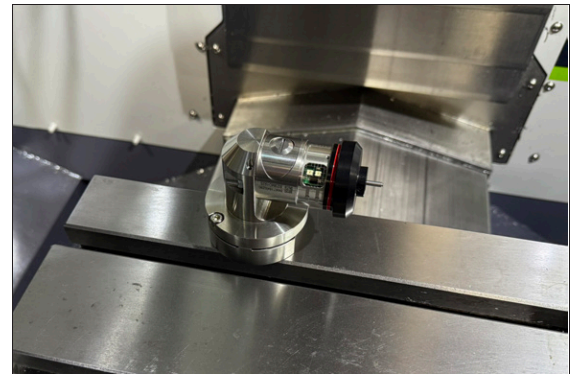


Figure 4-121: Tool setter installed onto the base ring.

4. Install the stylus onto the tool setter using a 1.5 mm hex wrench.



Figure 4-122: Stylus installed on the tool setter.

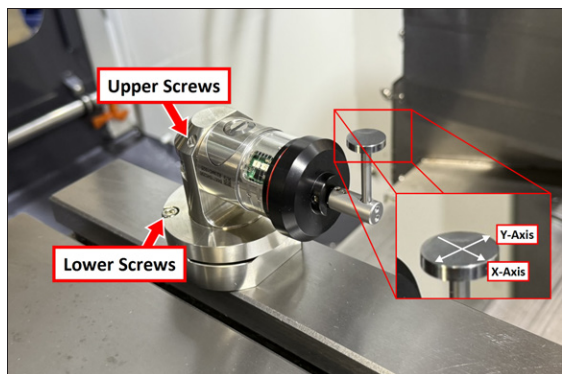
Align the Tool Setter's Stylus

The position of the stylus is controlled by two sets of screws on the tool setter:

4: INSTALLATION

4.7 Install Accessory Components

- Use the **lower screws** to adjust the X-axis.
- Use the **upper screws** to adjust the Y-axis.



The adjustments are made completely separately from one another, but you can make them in any order. We recommend adjusting until the dial indicator shows movement of less than 0.0005 inches in both directions.

1. Mount a dial indicator on the spindle, and carefully jog the indicator's tip to the top of the tool setter's stylus.

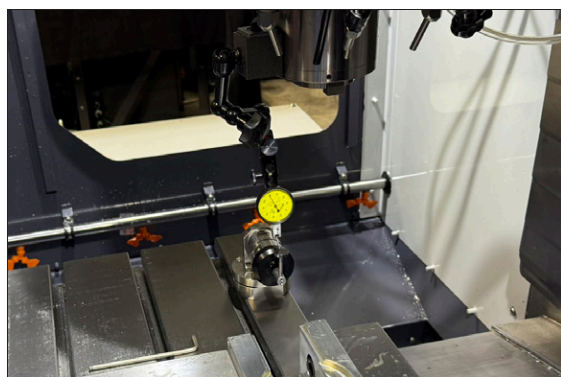


Figure 4-123: Dial indicator set up to check the flatness of the tool setter's stylus.

2. To adjust the X-axis of the tool setter, jog the indicator's tip to either the front or the back of the stylus and set the needle to zero. You'll always check from this side.
3. Sweep the indicator to the opposite side of the stylus and watch the needle.
4. Depending on the amount of movement, adjust the **lower screws** on the tool setter by slightly tightening one and loosening the other.
5. Jog the indicator's tip back to the opposite side of the stylus (where you originally started). Set the needle to zero, and sweep the indicator back to the opposite side of the stylus.
6. Continue adjusting and rechecking until the reading on the dial indicator is less than 0.0005 inches.

7. To adjust the Y-axis of the tool setter, jog the indicator's tip to either the left or the right of the stylus. You don't need to reset the indicator to zero — you'll just check for movement.
8. Sweep the indicator to the opposite side of the stylus and watch the needle.
9. Depending on the amount of movement, adjust the **upper screws** on the tool setter by slightly tightening one and loosening the other.
10. Continue adjusting and rechecking until the reading on the dial indicator is less than 0.0005 inches.

Reference the Tool Setter

1. Remove the tool setter's battery door using a flat-blade screwdriver or similar object.

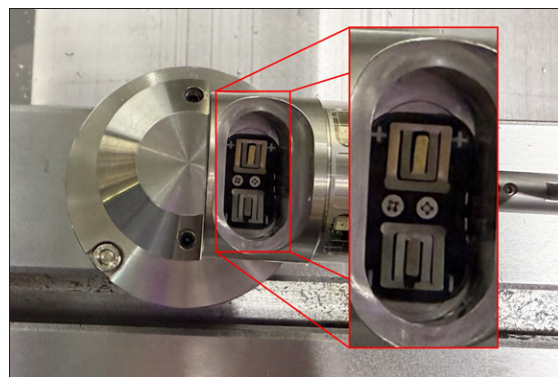


Figure 4-124: Battery door removed from the tool setter.

2. Identify the two batteries included with this kit. Put both batteries into the tool setter. Replace the battery door onto the tool setter, and secure it with a screwdriver.



Note: Do not depress the tool setter's stylus while inserting the batteries. Depressing the stylus will cause the tool setter to enter settings mode. If the stylus is depressed, wait one minute for the tool setter to exit settings mode.

3. Power on the machine and the PathPilot controller.
 - a. Turn the Main Disconnect switch to **ON** on the side of the electrical cabinet.
 - b. Twist out the machine's red Emergency Stop button, which enables movement to the machine axes and the spindle.
 - c. Press the machine's Reset button (next to the Emergency Stop button).
 - d. Bring the machine out of reset and reference it.
4. If you haven't already done so, enter the diameter and length for the calibration tool (engraved on the side of the tool) into PathPilot. From the PathPilot interface, on the **Offsets** tab, enter details into tool 1000.
5. Load the calibration tool into the spindle. From the PathPilot interface, in the **Tool DRO** field, type 1000 and press the **Enter** key on the keyboard.
6. Jog the machine table so that the tool setter is under the tool, and slowly jog the Z-axis down until it's just above the tool setter.

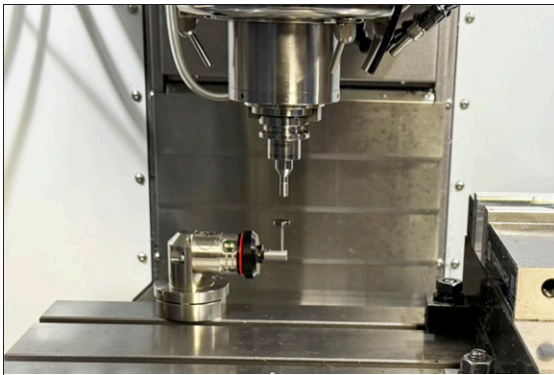


Figure 4-125: Calibration tool above the tool setter.

7. From the PathPilot interface, on the **Probe/ETS** tab, open the **ETS Setup** tab. Then, select **ETS Spindle Ref.**

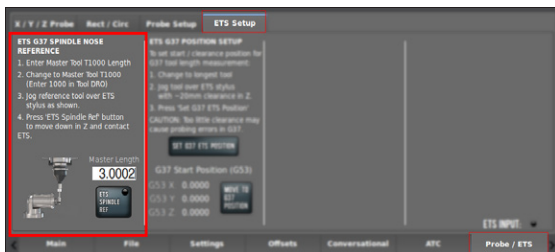


Figure 4-126: ETS Setup tab.

Set G37 Position

1. Load the longest tool that you'll be using into the spindle. From the PathPilot interface, change to that

tool.

NOTICE! If you use a shorter tool to set the G37 position, there's a risk of tool collision when using a longer tool.

2. Jog the tool so that it's about 20 mm above the tool setter's contact pad.
3. From the PathPilot interface, on the **ETS Setup** tab, find the **ETS G37 Position Setup** group, and select **Set G37 ETS Position**.

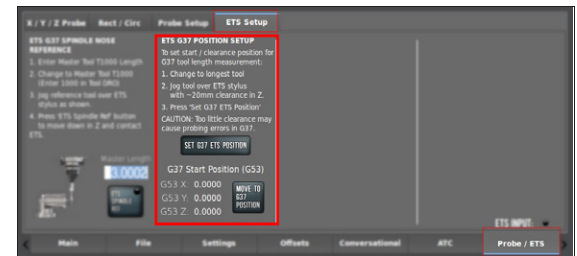


Figure 4-127: Set G37 ETS Position on the Probe tab.

The G37 position is now set.

4. Verify that the X, Y, and Z ETS position displayed in their DRO fields are accurate.



Note: The values displayed in these DRO fields are in G53.

Wireless Probe Installation and Setup

1. Identify the wireless probe included in this kit. Install it into the BT30 probe holder by tightening the two set screws opposite each other. Do not tighten the four-set-screw pattern at this time.



Figure 4-128: Installing the probe into the BT30 holder.

4: INSTALLATION

4.7 Install Accessory Components

2. Thread the probe tip into the wireless probe.

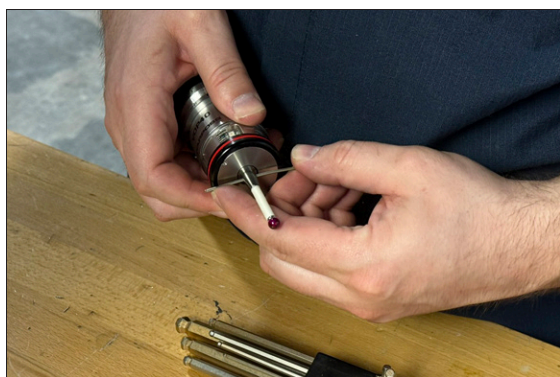


Figure 4-129: Installing the probe tip.

3. Remove the probe's battery door using a flat-blade screwdriver or similar object.
4. Insert two batteries into the wireless probe. The probe lights should illuminate; if they don't, you may need to swap the battery placement.



Figure 4-130: Battery door removed off of the wireless probe.



Note: While installing the cover, be careful not to deflect the probe tip. If you do, leave the probe for 30 seconds until the lights turn off.

5. Load the probe into the spindle.

Adjust Probe Tip Concentricity

1. Place a dial indicator on the machine table, and carefully jog the indicator's tip into the probe's tip to check for concentricity.



Figure 4-131: Dial indicator set up to check the probe's tip concentricity.

2. Identify the two sets of screws on the probe body. When you loosen one set screw, tighten the opposite set screw. Make adjustments as needed to the screws, manually rotate the probe by hand, and check the alignment again. Aim for the best possible concentricity, targeting between 0.0005 in. and 0.001 in.



Figure 4-132: Both sets of screws are shown; not shown are each set's opposing screw.

Set Probe Length and Diameter

1. Identify the calibration tool (PN 51149) included with this kit. Load the calibration tool into the spindle. Make note of the diameter and length, which is engraved on the tool itself.

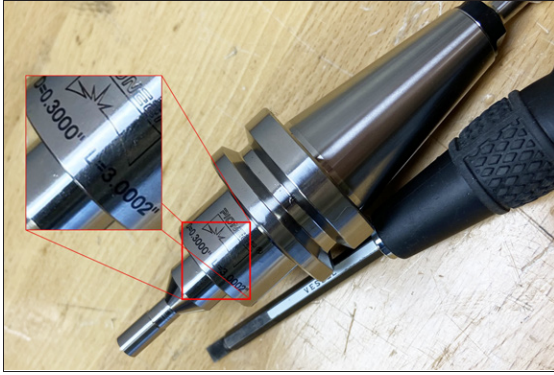


Figure 4-133: Diameter and length measurements engraved on to the calibration tool.

- From the PathPilot interface, on the **Offsets** tab, enter the diameter and length for the calibration tool into tool 1000.
- Wipe off the machine table.
- Put a 1-2-3 block on the machine table.
- Verify that the machine is in setup mode. Use the key on the top of the operator console to switch between modes. For more information, go to Operating Modes Reference.



Figure 4-134: PathPilot indication of which mode the machine is set to.

Note: In setup mode, you don't need to press the hold-to-run button to jog the machine with the enclosure doors open.

- Jog the table until the block is under the calibration tool. Slowly jog the Z-axis down until it's tip drags on the 1-2-3 block.



Figure 4-135: Calibration tool near the top of the 1-2-3 block.

- Close the enclosure door.
- From the PathPilot interface, change to T1000.
- From the **Probe/ETS** tab, on the **Probe Setup** tab, select **Set Reference Height**.



Figure 4-136: Reference height section of the probe setup.

- Remove the calibration tool and load the probe into the spindle.
- From the PathPilot interface, change to T99. Make sure the probe LED turns green. While watching the LED, flick the probe tip to make sure that the probe responds.

4: INSTALLATION

4.7 Install Accessory Components

12. Jog the table until the 1-2-3 block is under the probe. Slowly jog the Z-axis down until the probe's tip is just above the 1-2-3 block.



Figure 4-137: Probe tip near the top of the 1-2-3 block.

13. From the PathPilot interface, on the **Probe/ETS** tab, open the **Probe Setup** tab. Then, select **Move and Set Probe Length**.

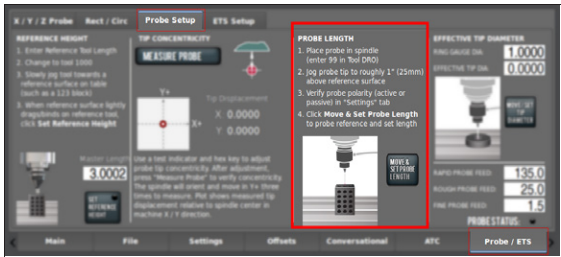


Figure 4-138: Probe length section of the probe setup.

14. Identify the ring gauge (PN 51100) included in this kit. Make note of the diameter, which is engraved on the side of the ring gauge.

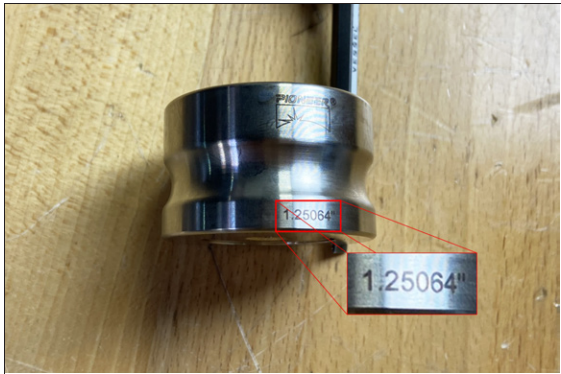


Figure 4-139: Diameter measurement engraved onto the ring gauge.

15. Place the ring gauge on the machine table, and jog the spindle probe so that it's in the center of the ring gauge and 1/4 in. below the ring gauge's surface.

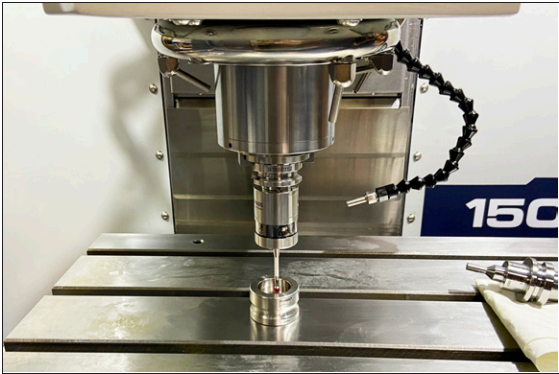


Figure 4-140: Ring gauge under the spindle.

16. Close the enclosure door.
17. From the PathPilot interface, on the **Probe** tab, enter the diameter of the ring gauge into the **Ring Gauge Diameter DRO** field. Then, select **Move/Set Tip Diameter**.



Figure 4-141: Effective tip diameter section of the probe setup.

Probe Status Lights Reference

Light	Status
Blinking green	The probe is on and triggered
Blinking red	Error
Blinking yellow	The probe's battery signal is low

4.8 SET UP THE PATHPILOT CONTROLLER

Before operating your machine, configure in PathPilot the date, time, keyboard language, and — if applicable — the optional Touch Screen Kit (PN 35575).

4.8.1 Specify the Date and Time

1. From the PathPilot interface, on the **Main** tab, in the **MDI Line** DRO field, type `ADMIN DATE`. Then select the **Enter** key.

The **Time and Date Settings** dialog box displays.



Note: Before using any ADMIN commands, you must release the Emergency Stop. Rotate the Emergency Stop button one quarter turn to release it.

2. Complete the fields in the **Time and Date Settings** dialog box, and then select **Close**.

4.8.2 Specify the Keyboard Language

By default, the keyboard language is set to English.

To specify a different keyboard language:

1. From the PathPilot interface, on the **Main** tab, in the **MDI Line** DRO field, type `ADMIN KEYBOARD`. Then select the **Enter** key. The **Keyboard Preferences** dialog box displays.
2. Select the **Layouts** tab and select the desired language. If the language you want is not listed, select **Add** to specify the language. Then, select **Close**.

4.8.3 Configure the Optional Touch Screen Kit

Before using a touch screen, you must make sure that it's configured and calibrated. To calibrate it:

1. From the PathPilot interface, on the **Main** tab, in the **MDI Line** DRO field, type `ADMIN TOUCHSCREEN`. Then select the **Enter** key.
2. Follow the on-screen instructions.

4.8.4 Update PathPilot

We're constantly updating PathPilot to bring you more features. Before operating your machine, update to the latest version.

1. Confirm that the PathPilot controller is powered on and out of **Reset** mode.
2. Downloading and installing an update file requires an

Internet connection. From the **Status** tab, confirm that the **Internet** button LED light is on. (To configure the network, select the LED light.) Then, select **Update**.



Figure 4-142: Update button on the Status tab.

3. From the **Software Update** dialog box, select **Check Online**.

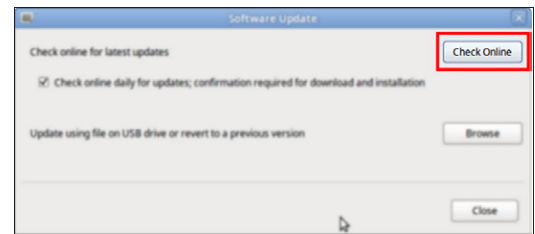


Figure 4-143: Software Update dialog box.

4. Select **Install**.



Figure 4-144: Install button on the Software Update dialog box.

The update file is downloaded, and a notification dialog box displays.

5. From the dialog box, select **OK**. The update file is installed on the PathPilot controller.
6. Follow the on-screen instructions to restart the PathPilot controller.



SYSTEM BASICS

IN THIS SECTION, YOU'LL LEARN:

- About the main components of the machine and how it moves.



Before operating the machine in any way, you must read and understand this section.

CONTENTS

5.1 System Reference.....	102
5.2 Basic Controls Reference.....	103



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5: SYSTEM BASICS

5.1 System Reference

5.1 SYSTEM REFERENCE

To operate your machine, you must become familiar with the components of its system.

5.1.1 Machine Table

The machine table is 26" x 8" (660 mm x 203 mm).

Don't put more than 400 lb (181 kg) on the machine table.

Always verify that the workpiece and workholding devices are centered on the machine table.

The machine table has three T-slots along the X-axis, used to secure workholding devices (on which to secure your workpiece while machining):

- **T-Slots** 5/8" (15.9 mm) (three slots)
- **T-Slot Spacing** 2-3/8" (60.3 mm)
- **Center T-Slot** Precision ground to 0.625" (15.9 mm)

5.1.2 Spindle

The machine spindle uses a BT30 taper to hold BT30 tool holders.

- **Spindle Power** 2 hp (1.5 kW)
- **Minimum Speed** 250 rpm
- **Maximum Speed** 10,000 rpm

About the Spindle

The machine spindle gives power to the cutting tool, which allows it to remove material from the workpiece. The spindle is driven by the spindle motor.

The machine uses a single-contact BT30 spindle taper. The tool holder contacts only the spindle taper, which keeps it in position. Because of this, there's a gap (2 mm) between the tool holder's flange and the end surface of the spindle nose. Operate the spindle either manually or by G-code commands (entered in the MDI Line DRO field or programmed into a G-code program). Manually controlling the spindle is useful when you're setting work offsets for tools that require the spindle to be running (like "wiggler"-style edgefinders or coaxial indicators).

The machine's spindle rotates either clockwise (forward) or counterclockwise (reverse) at a specified spindle speed.

5.1.3 Axes

The machine has three linear axes of motion, and one optional rotary axis, used for machining:

- The X-axis, which is (horizontally) along the long side of the machine table.

- The Y-axis, which is (horizontally) along the short side of the machine table.
- The Z-axis, which is (vertically) along the mill column.
- *(Optional)* The A-axis, which is the axis of rotation that is typically aligned to the X-axis.

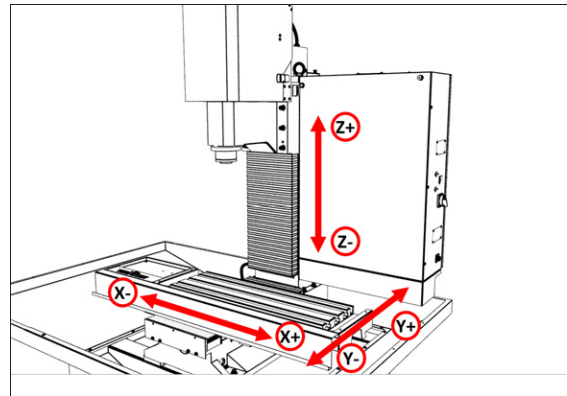


Figure 5-1: Axis directions on the machine.

Each axis has a different limit of travel:

- **X-Axis** 14" (356 mm)
- **Y-Axis** 7.5" (191 mm)
- **Z-Axis** 13.25" (337 mm)

5.2 BASIC CONTROLS REFERENCE

To safely and effectively operate your machine, you must become familiar with how it moves. The machine has two forms of basic controls: machine controls and the PathPilot interface.

5.2.1 Machine Controls

The following controls energize the machine's control electronics:

- The Main Disconnect switch, located on the right side of the electrical cabinet.

The Main Disconnect switch has two positions: **OFF** and **ON**. When it's in the **OFF** position, it separates the other machine control electronics from the mains electrical supply. When it's in the **ON** position, the other machine control electronics are able to receive power.



WARNING! Before opening the electrical cabinet for maintenance or troubleshooting, you must lockout the mains power: Turn the Main Disconnect switch to the **OFF** position, and secure an approved lockout device through the lockout rings at the bottom of the switch.

- The blue Reset button and the red Emergency Stop button, located on the front of the machine.
When pushed in, the Emergency Stop button interrupts power to the spindle and axis drives, and stops the machine's motion. When the Emergency Stop button is twisted out, press the Reset button to enable the machine, allowing spindle and axis motion. The Reset button's LED turns on when the machine is enabled and the spindle and axis drives receive power.

5.2.2 PathPilot Interface

PathPilot is the primary means by which you interact with your machine. PathPilot controls all of the automatic motion of the machine axes and spindle, as well as some accessories. The PathPilot control system consists of:

- **Controller and Monitor** Shows the PathPilot interface (monitor, touch screen, or integrated console display)
- **Input Devices** Keyboard and mouse for navigation and data entry

- **Manual Control** Jog pendant or jog shuttle for manual axis movement

The specific hardware configuration depends on your machine model.



PATHPILOT INTERFACE OVERVIEW

IN THIS SECTION, YOU'LL LEARN:

- How PathPilot is organized, and where you can access each tool or feature.

CONTENTS

6.1 About PathPilot	106
6.2 Notebook Section	107
6.3 Persistent Controls	110
6.4 Keyboard Shortcuts	112
6.5 Manage PathPilot Versions	113

6: PATHPILOT INTERFACE OVERVIEW

6.1 About PathPilot

6.1 ABOUT PATHPILOT

PathPilot is a combination hardware and software system that you use to control your machine. The controller hardware runs the PathPilot software.

The PathPilot interface is divided into sections: the Notebook section is in the top half of the screen, and the Persistent Controls section is in the bottom half.

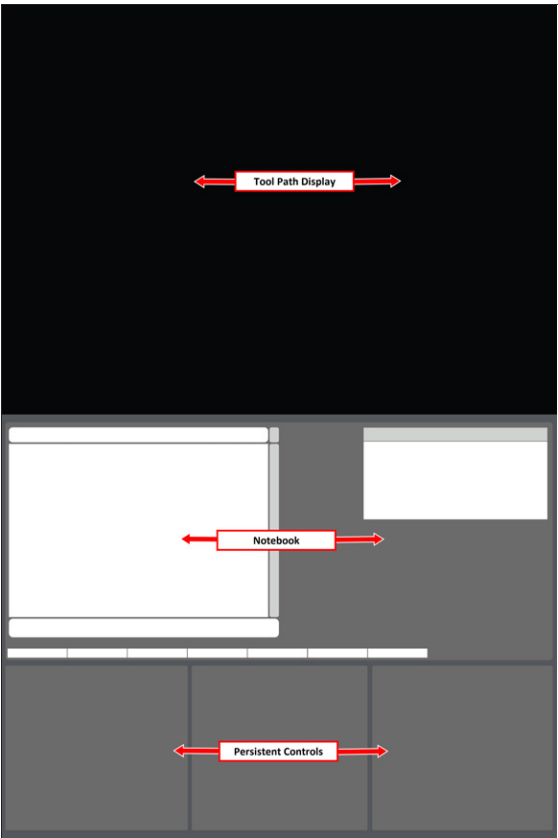


Figure 6-1: Sections in the PathPilot interface.

6.2 NOTEBOOK SECTION

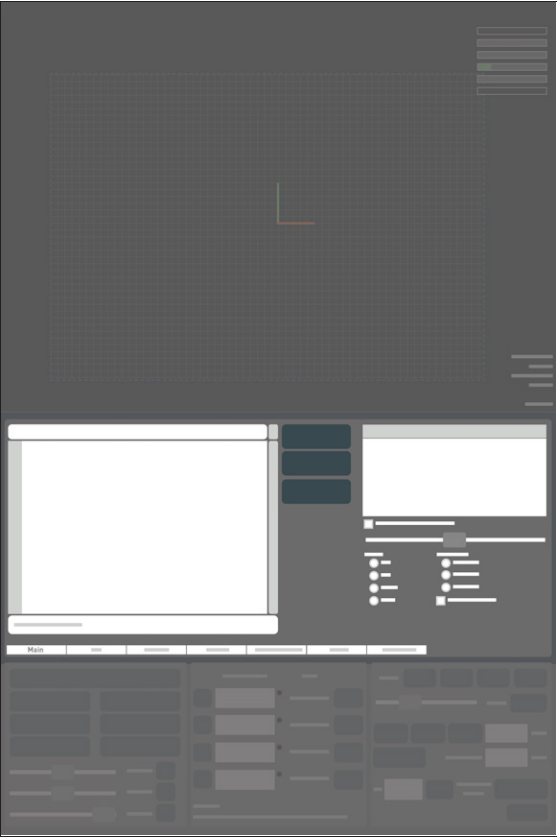


Figure 6-2: Notebook section.

The areas displayed in the Notebook section change depending on the activity that you're doing. Activities are grouped into the following tabs:

6.2.1 Main Tab	107
6.2.2 File Tab	107
6.2.3 Settings Tab	108
6.2.4 Offsets Tab	108
6.2.5 Conversational Tab	108
6.2.6 Probe/ETS Tab	108
6.2.7 Status Tab	109

6.2.1 Main Tab



Figure 6-3: Main tab.

By default, the Main tab is active when you power on the PathPilot controller. From the Main tab, you can do the following activities:

- Access G-code files that are already loaded into PathPilot, and open or close them.
For information, see "Access Recent G-Code Files" (page 117); "Close the Current Program" (page 117).
- Send G-code commands directly to the machine using the Manual Data Input (MDI) Line DRO field.
For information, see "Manually Enter Commands" (page 158).
- In a G-code program, do tasks like finding specific terms in the code, reading the code, or viewing the generated tool path.
For information, see "Search in the Code" (page 119); "Expand the G-Code Tab" (page 118); "Change the View of the Tool Path Display" (page 120).
- Make and restore backup files of your settings.
For information, see "Create Backup Files" (page 164); "Restore Backup Files" (page 165).

6.2.2 File Tab



Figure 6-4: File tab.

From the File tab, you can do the following activities:

- Transfer G-code files into the PathPilot controller.
For information, see "Transfer Files to and From the Controller" (page 174).
- Edit G-code files.
For information, see "Edit G-Code" (page 117).
- Load .nc files into PathPilot to run a program.
For information, see "Load G-Code" (page 174).
- Move files within the system.
For information, see "Preview G-Code Files" (page 116); "Manage System Files" (page 164).

6: PATHPILOT INTERFACE OVERVIEW

6.2 Notebook Section

6.2.3 Settings Tab

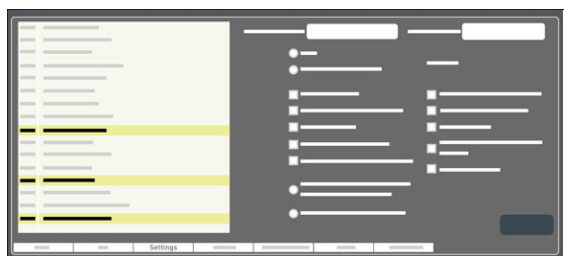


Figure 6-5: Settings tab.

From the Settings tab, you can do the following activities:

- Change the network name with which you're using PathPilot.
For information, see "Change the Network Name" (page 134).
- Change the screen's layout orientation (landscape or portrait).
For information, see "Change the Screen Orientation" (page 134).
- Configure PathPilot for the accessories you're using.
For information, see "Enable the On-Screen Keyboard" (page 137); "Enable the USB M-Code I/O Interface Kit" (page 138); "Use a USB Camera" (page 140); "Specify the Tool Change Method" (page 136); "Select the Spindle Type" (page 134) "Select the Spindle Type" (page 134).
- Turn on feeds and speeds suggestions when using conversational programming.
For information, see "Enable Feeds and Speeds Suggestions in Conversational Routines" (page 139).
- Specify the way in which you want to use a G30 move.
For information, see "Limit G30 Moves" (page 137).
- Identify the available G-code modes that you can use.
For information, see "View Available G-Code Modes" (page 149).

6.2.4 Offsets Tab



Figure 6-6: Offsets tab.

From the Offsets tab, you can do the following activities:

- Import and export .csv files of your tool table.
For information, see "Import and Export the Tool Table" (page 166).
- Work with a table of tool descriptions and tool offsets.
For information, see "Set Tool Length Offsets" (page 176).
- Use an Electronic Tool Setter (ETS) to measure tools.
For information, see "Use an Electronic Tool Setter (ETS) to Measure Tools" (page 178).
- Preset a G30 position.
For information, see "Use a G30 Position" (page 158).
- Read the currently programmed work offsets.
For information, see "View Work Offsets" (page 149).

6.2.5 Conversational Tab



Figure 6-7: Conversational tab.

From the Conversational tab, you can do the following activities:

- Use different functions to create simple G-code programs in PathPilot.
For information, see "About Conversational Programming" (page 121).

6.2.6 Probe/ETS Tab



Figure 6-8: Probe tab.

From the Probe tab, you can do the following activities:

- Configure and control a probe to help perform certain functions.
For information, see "Use a Probe with PathPilot" (page 143).

- Configure and control an Electronic Tool Setter (ETS) to help perform certain functions.
For information, see Use an to Measure Tools.

6.2.7 Status Tab

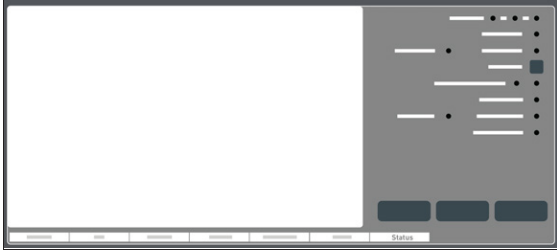


Figure 6-9: Status tab.

From the Status tab, you can do the following activities:

- View diagnostic machine information.
For information, see Troubleshooting.
- Read error messages.
- Configure your internet connection.
For information, see "Enable an Internet Connection" (page 133).
- Update or install a previous version of PathPilot.
For information, see "Manage PathPilot Versions" (page 113).

6: PATHPILOT INTERFACE OVERVIEW

6.3 Persistent Controls

6.3 PERSISTENT CONTROLS

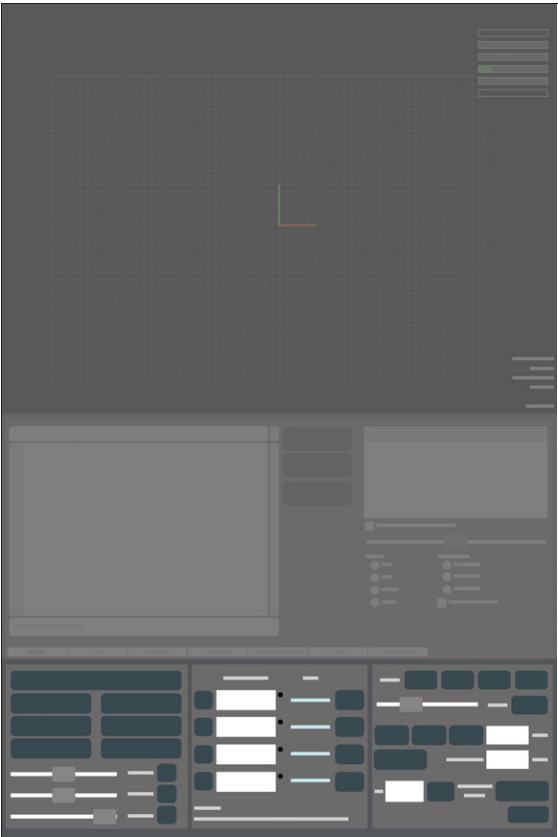


Figure 6-10: Persistent Controls section.

The areas that display in the Persistent Controls section don't change (unlike the Notebook section). They display regardless of the activity you're doing. Activities are grouped into the following areas:

6.3.1 Program Control Area	110
6.3.2 Position Status Area	110
6.3.3 Manual Control Area	111

6.3.1 Program Control Area



Figure 6-11: Program Control area.

From the Program Control area, you can do the following activities either before starting or while running a G-code program:

- Reset the machine.
For information, see "Bring the Machine Out of Reset" (page 169).
- Start, stop, or pause a G-code program.
For information, see "Start a Program" (page 152); "Stop Machine Motion" (page 153); "Use the Feed Hold Function" (page 154).
- Turn coolant on or off.
For information, see "Operate the Coolant Pump" (page 181).
- Use overrides to change the feed rate, spindle speed, and maximum velocity.
For information, see "Use the Feed Rate Override Function" (page 154); "Use the Maxvel Override Function" (page 155); "Use the Spindle Override Function" (page 156).
- Manually control a G-code program.
For information, see "Use M01 Break Mode" (page 155); "Use Single Block Mode" (page 156).

6.3.2 Position Status Area



Figure 6-12: Position Status area.

From the Position Status area, you can do the following activities either before starting or after running a G-code program:

- Reference the machine axes.
For information, see "Reference the Machine" (page 170).
- Create work offsets.
For information, see "Set Work Offsets" (page 180).
- Understand how you're jogging the machine.
For information, see "View the Active Axis to Jog" (page 150); "View the Current Machine Position" (page 151); "View the Distance to Go" (page 153).
- Quickly determine which G-code modes are active.
For information, see "View the Active G-Code Modes" (page 153).

6.3.3 Manual Control Area



Figure 6-13: Manual Control area.

From the Manual Control area, you can do the following activities either before starting or after running a G-code program:

- Move the machine axes.
For information, see "Jog the Machine" (page 171).
- Change the spindle speed or feed rate.
For information, see "Change the Spindle Speed" (page 157); "Change the Feed Rate" (page 157).
- View or edit information about the current tool.
For information, see "Change the Tool Number" (page 157); "Use a G30 Position" (page 158) "View the Tool Length" (page 158).

6: PATHPILOT INTERFACE OVERVIEW

6.4 Keyboard Shortcuts

6.4 KEYBOARD SHORTCUTS

The following table lists the keyboard shortcuts in PathPilot.

Keyboard Shortcut	Use to...
Alt+E	Edit the currently loaded G-code program (from any tab in the PathPilot interface)
Alt+Enter	Use the Manual Data Input (MDI) Line DRO field
Alt+F	Use the coolant function
Alt+R	Start a program
Esc	Stop a program
Shift+Alt+E	From the Main tab, quickly edit a G-code program with conversational programming
Space Bar	Feed hold the machine

6.5 MANAGE PATHPILOT VERSIONS

You don't need to install updates sequentially. You can update from any previous version to the current version of PathPilot. Depending on what you want to do, refer to the following sections:

- "Download and Install an Update File from the Controller" (below)
- "Install an Update File from a USB Drive" (below)
- "Install a Previous Version of an Update File" (on the next page)

6.5.1 Download and Install an Update File from the Controller

1. Confirm that the PathPilot controller is powered on and out of **Reset** mode.
2. Downloading and installing an update file requires an Internet connection. From the **Status** tab, confirm that the **Internet** button LED light is on. (To configure the network, select the LED light.) Then, select **Update**.

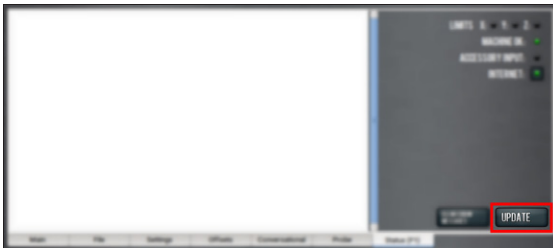


Figure 6-14: Update button on the Status tab.

3. From the **Software Update** dialog box, select **Check Online**.

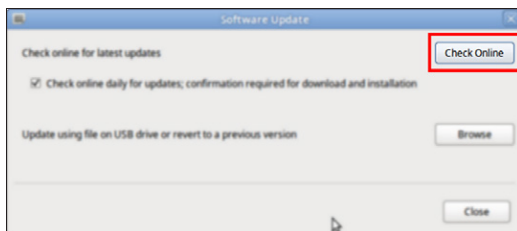


Figure 6-15: Software Update dialog box.

4. Select **Install**.



Figure 6-16: Install button on the Software Update dialog box.

The update file is downloaded, and a notification dialog box displays.

5. From the dialog box, select **OK**.
The update file is installed on the PathPilot controller.
6. Follow the on-screen instructions to restart the PathPilot controller.

6.5.2 Install an Update File from a USB Drive

1. From the PathPilot support center, download the most recent PathPilot update file.
2. Transfer the PathPilot update file to a USB drive.
3. Put the USB drive into the PathPilot controller.
4. Confirm that the PathPilot controller is powered on and out of **Reset** mode.
5. From the **Status** tab, select **Update**.

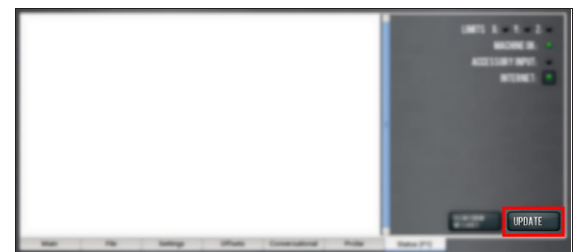


Figure 6-17: Update button on the Status tab.

6. From the **Software Update** dialog box, select **Browse**.

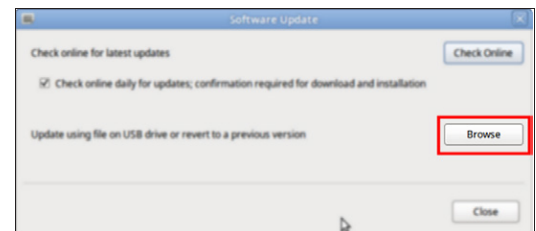


Figure 6-18: Software Update dialog box.

6: PATHPILOT INTERFACE OVERVIEW

6.5 Manage PathPilot Versions

- 7. From the **Browse** dialog box, select **USB**.



Figure 6-19: Browse dialog box.

- 8. Select the desired update file, and then select **Update**.
The update file is installed on the PathPilot controller.
- 9. Follow the on-screen instructions to restart the PathPilot controller.

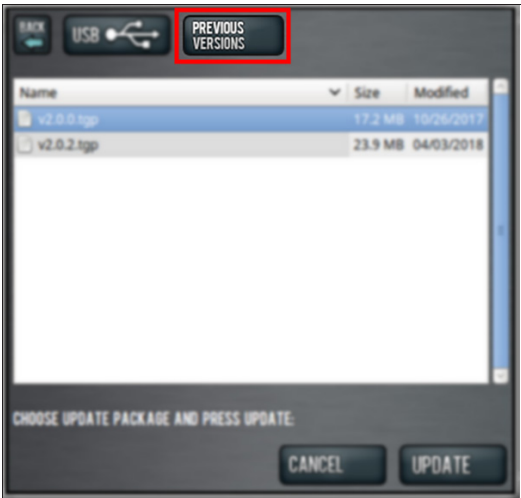


Figure 6-22: Browse dialog box.

- 5. Select the desired update file, and then select **Update**.
The update file is installed on the PathPilot controller.
- 6. Follow the on-screen instructions to restart the PathPilot controller.

6.5.3 Install a Previous Version of an Update File

- 1. Confirm that the PathPilot controller is powered on and out of **Reset** mode.
- 2. From the **Status** tab, select **Update**.

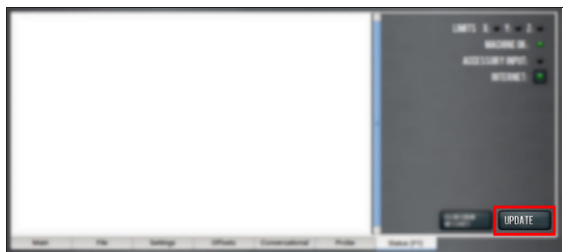


Figure 6-20: Update button on the Status tab.

- 3. From the **Software Update** dialog box, select **Browse**.

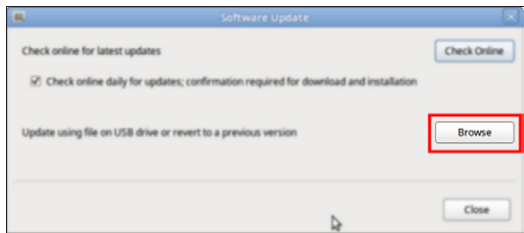


Figure 6-21: Software Update dialog box.

- 4. From the **Browse** dialog box, select **Previous Versions**.

PATHPILOT TOOLS AND FEATURES

IN THIS SECTION, YOU'LL LEARN:

- How to use PathPilot, depending on the activity that you want to do.

CONTENTS

7.1 Create and Load G-Code Files.....	116
7.2 Machine Settings and Accessories.....	133
7.3 Set Up G-Code Programs.....	143
7.4 Run G-Code Programs.....	150
7.5 Control G-Code Programs.....	154
7.6 System File Management.....	164

7: PATHPILOT TOOLS AND FEATURES
7.1 Create and Load G-Code Files

7.1 CREATE AND LOAD G-CODE FILES

To get started with PathPilot, you must first load or create a G-code file.

7.1.1 Load G-Code 116
7.1.2 Edit G-Code 117
7.1.3 Read G-Code 118
7.1.4 Use Conversational Programming 121

7.1.1 Load G-Code

To run a G-code program on a PathPilot controller, you must first verify that the file is on the controller. For more information on transferring and moving files, see "Transfer Files to and From the Controller" (page 174).

To load G-code:

- 1. From the File tab, in the Controller Files window, select the desired .nc file.
- 2. Select Load.

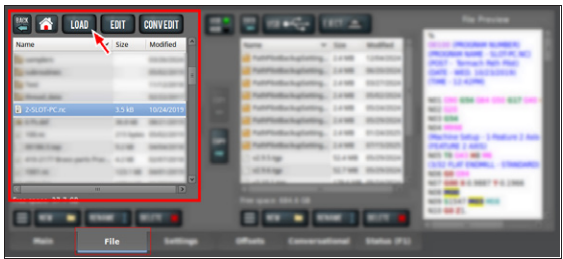


Figure 7-1: Controller Files window on the File tab.

Note: This function is only available for files stored on the PathPilot controller.

PathPilot loads the G-code file and opens the Main tab.

Transfer Files to and From the Controller

To run a G-code program, you must transfer the files to the PathPilot controller. You can either use a USB drive or PathPilot HUB (our cloud-based simulator) to transfer files. For more information on PathPilot HUB, go to hub.pathpilot.com.

To transfer files to and from the controller:

- 1. Either insert a USB drive into any open USB port, or sign in to PathPilot HUB.
- 2. From the File tab, select the file to transfer (either in the USB / HUB Files window or the Controller Files window).

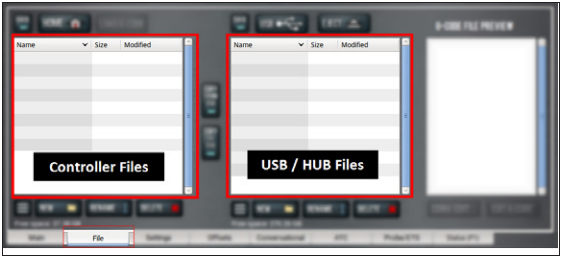


Figure 7-2: File tab.

Note: Select Back to move backward and either Home or USB to move to the highest level.

- 3. Select the location to which you want to copy the transferred file.
- 4. Select either Copy ← or Copy →.

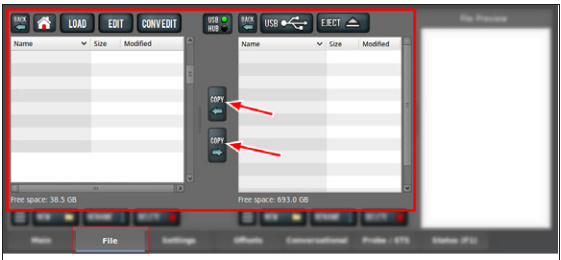


Figure 7-3: File tab.

Note: The file must have a unique name. If it doesn't, you must either overwrite the file, rename the file, or cancel the file transfer.

- 5. If you're using a USB drive, select Eject. It's safe to remove the USB drive from the controller.

Preview G-Code Files

You can preview an .nc file that's either on the PathPilot controller or on a USB drive.

To preview G-code files:

- From the File tab, in the Controller Files window or the USB Files window, select an .nc file. The text displays in the Preview window.

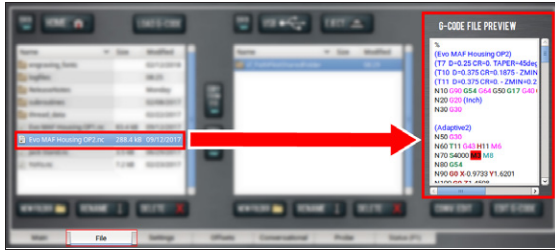


Figure 7-4: File tab.

Access Recent G-Code Files

You can load a recently loaded G-code file from the Main tab. For information, see "About the G-Code Tab" (on the next page).

To access recent G-code files:

1. From the **Main** tab, in the **G-Code** tab, select the **Recent Files** menu.

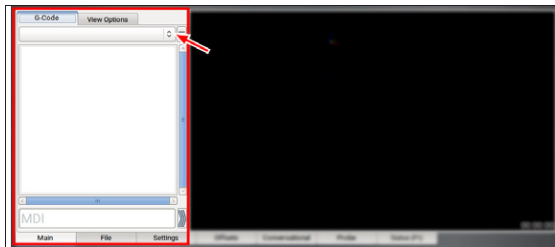


Figure 7-5: Recent Files menu on the Main tab.

The last five program files loaded into PathPilot display.

2. Select the name of the desired G-code program.
The G-code program loads.

Close the Current Program

1. From the **Main** tab, on the **G-Code** tab, select the **Recent Files** menu.
2. Select **Clear Current Program**.

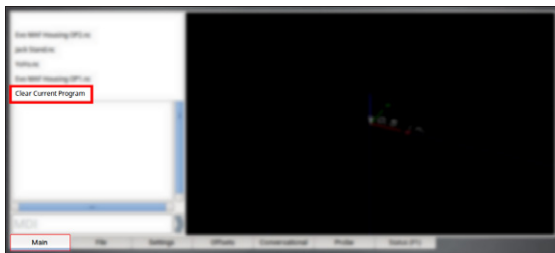


Figure 7-6: Recent Files menu on the Main tab.

The currently loaded G-code program closes.

7.1.2 Edit G-Code

In PathPilot, there are two ways to edit G-code:

- **Edit G-Code with a Text Editor** 117
- **Edit G-Code with Conversational Programming** 117

Edit G-Code with a Text Editor

You can edit .nc files that are on the PathPilot controller. If the .nc file is in the USB Files window, you must first transfer it to the controller; go to "Transfer Files to and From the Controller" (page 174).

To edit G-code with a text editor:

1. From the **Controller Files** window, highlight the .nc file and select **Edit G-code**.

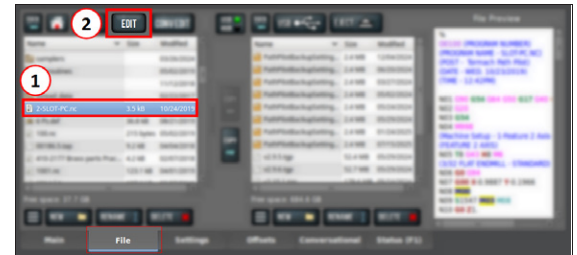


Figure 7-7: Edit G-code button on the File tab.

The file opens in a text editor.

2. Make and save the appropriate changes to the file.
3. Close the text editor.

Tip! To quickly edit an already loaded G-code program from the Main tab, you can use a keyboard shortcut: Shift+Alt+E.

Edit G-Code with Conversational Programming

You can edit .nc files that are on the PathPilot controller. If the .nc file is in the USB Files window, you must first transfer it to the controller; go to "Transfer Files to and From the Controller" (page 174).

To edit G-code with conversational programming:

7: PATHPILOT TOOLS AND FEATURES
7.1 Create and Load G-Code Files

- 1. From the File tab, select the .nc file.
 - 2. Select Conv. Edit.
- The file opens in a job assignment editor window: the program's job assignments are on the left and a preview of the program is on the right.

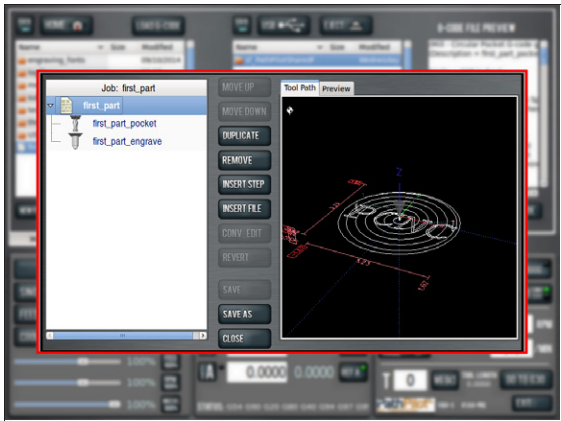


Figure 7-8: Job assignment editor.

- 3. Edit the file contents as needed. Do any of the following:
- | | |
|-----------------------------------|-----|
| Change the Step Order..... | 118 |
| Create a New Job Assignment..... | 118 |
| Load an Existing G-Code File..... | 118 |
| Edit a Job Assignment..... | 118 |
- 4. Select Save.
- The G-code program file is updated.

Change the Step Order

- Select Move Up, Move Down, Duplicate, or Remove.

Create a New Job Assignment

- 1. Select Insert Step.
- PathPilot opens the Conversational tab.
- 2. Create the new job assignment.
- 3. Select Insert.
- 4. (Optional) Edit the job assignment order in the program.

Load an Existing G-Code File

- 1. Select Insert File. You can insert G-code files that are hand-written, generated from CAM software, or generated from conversational programming in PathPilot.
- 2. Navigate to and select the .nc file that you want to insert.
- 3. Select Open.
- 4. (Optional) Edit the job assignment order in the program.

Edit a Job Assignment

- 1. Select the job assignment, and then select Conv. Edit. PathPilot opens the Conversational tab.
- 2. Edit the job assignment.
- 3. Select Finish Editing.

Tips

- To restore an edited job assignment to its original parameters: select Revert.

**Note:** Revert is only available for individual job assignments created in conversational programming.

- To undo all changes made to an entire G-code program: select Close. When prompted, select Close Without Saving.

7.1.3 Read G-Code

Once your G-code file is loaded into PathPilot, you can read it in the following ways:

Expand the G-Code Tab.....	118
Search in the Code.....	119
Set a New Start Line.....	119
Change the View of the Tool Path Display.....	120

Expand the G-Code Tab

You can change the size of the G-Code tab if you need more space to view the code. For more information on using the G-Code tab, see "About the G-Code Tab" (below).

To expand the G-Code tab:

- Select the Window Expander.

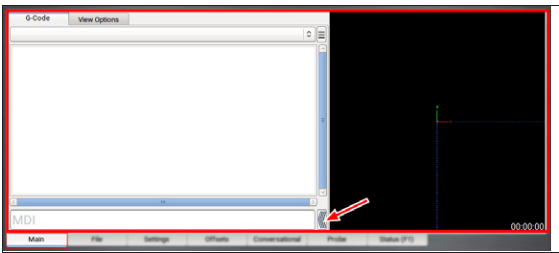


Figure 7-9: Window Expander on the Main tab.

The Tool Path display shrinks.

About the G-Code Tab

The G-Code tab displays the code of the currently loaded program file. Use the scroll bars to view the entire file. You

can make the G-Code tab larger. For information, see "Expand the G-Code Tab" (on the previous page).

PathPilot highlights certain lines of code of interest. When running a G-code program in single block mode, there may be as many as two lines of G-code highlighted, both with a different color:

- **Green Line** Indicates the start line (the line from which PathPilot starts the program).
To change the start line, go to "Set a New Start Line" (below).
- **Orange Line** Indicates the line of code that PathPilot is currently executing.

Search in the Code

You can use PathPilot to search the text of a G-code program file for specific numbers, codes, or other items of interest (like tools, feeds, and speeds).

To search in the code:

1. From **Main** tab, on the **G-Code** tab, select any line of code to use as a starting point.
2. In the **MDI Line DRO** field, type **FIND** followed by one of the following:
 - Any text. PathPilot searches for instances of the specific number or code.

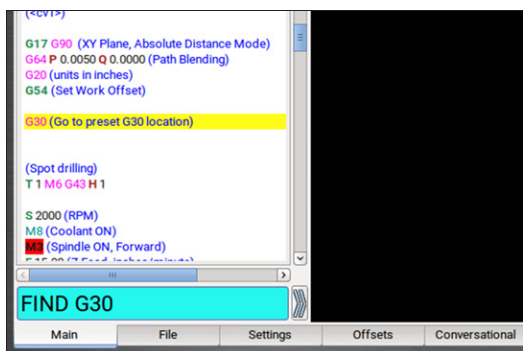


Figure 7-10: Search for a text command.

- **FEED.** PathPilot searches for instances of the actual word **Feed** and any **F** G-code command.

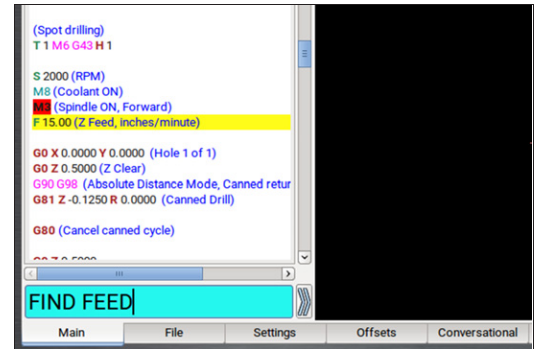


Figure 7-11: Search for a feed command.

- **SPEED.** PathPilot searches for instances of the actual word **Speed** and any **S** G-code command.
- **TOOL.** PathPilot searches for instances of the word **Tool** and any **T** G-code command.



Note: The find command is not case-sensitive.

3. Select the **Enter** key.
If PathPilot finds the information, the searched term is scrolled to and highlighted in the **G-Code** tab.
4. *(Optional)* Select **Enter**.
PathPilot finds the next instance of the searched text.
5. *(Optional)* Select **Enter+Shift**.
PathPilot finds the previous instance of the searched text.



Note: When the search reaches the end of the G-code file, it starts again from the beginning.

Set a New Start Line

The start line (the line from which PathPilot starts the program) is, by default, the first line of code in the program. To set a new start line:

1. From the **Main** tab, on the **G-Code** tab, do one of the following:

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files

- Right-click any line in the program.

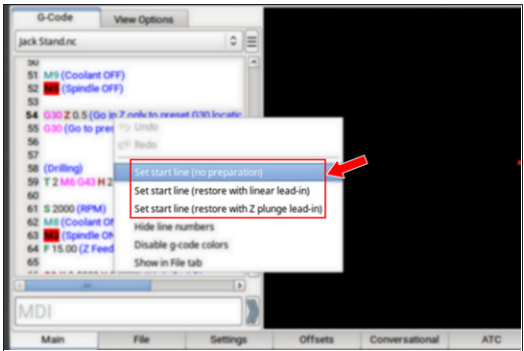


Figure 7-12: Accessing the Options menu by right-clicking.

- Tap the line. Then, select the **Options** menu.
2. Select the desired lead-in move. For information, see "Lead-In Moves" (below).

Lead-In Moves

- **Set start line (no preparation)** Keep the current tool in the spindle, with the current tool length applied. The machine executes the start line from the current position.



Note: We don't recommend this option for starting partway through a cut.



EXAMPLE

- Starting the program at a tool change.
- Starting the program with a different tool in the spindle than the program calls for (like if your tool broke, which you've replaced, but you'd rather not edit the entire program or the tool table entry).

- **Set start line (restore with linear lead-in)** Perform a tool change (as required). The machine rapids in X and Y, then Z to the current position, then feeds in a straight linear line to the start line position.



Note: This option assumes that the current position is the lead-in position.



EXAMPLE

Quickly resuming work after stopping the program to make an adjustment to the machine setup (like clearing chips, removing an object, or turning on the coolant pump). Because the machine's already set up, you can position the tool near the stopping point.

- **Set start line (restore with Z plunge lead-in)**

Perform a tool change (as required). The machine rapids in Z to G30 clearance height, rapids in X and Y to the start line position, then feeds in Z to the start line position.



EXAMPLE

Running a sub-section of a large program when the correct tool isn't loaded (and positioning the tool tip near the starting point is difficult, like with a long tool loaded). This option doesn't require you to jog to the exact lead-in position.

Change the View of the Tool Path Display

1. From the **Main** tab, do one of the following:
- Right-click the **Tool Path** display.

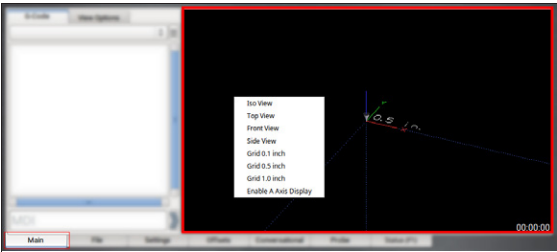


Figure 7-13: Tool Path display on the Main tab.

- Select the **View Options** tab.

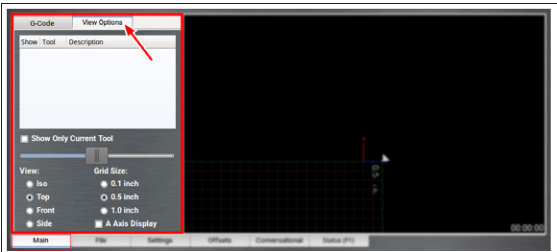


Figure 7-14: View Options tab on the Main tab.

2. Select a new view.
For information, see "About the Tool Path Display" (below).

About the Tool Path Display

The Tool Path display is a graphical representation of the currently loaded G-code file's tool path.

There are four available views:

- Front
- Iso
- Side
- Top

You can see grid lines behind the tool path while you are using either a Top, Front, or Side view. Depending on which programming mode you're in (G20 or G21), PathPilot defaults to one of the following grid line spacings:

- **G20 Mode** 1/2 in. intervals
- **G21 Mode** 10 mm intervals

In the Tool Path display, there are four different line types:

- **Dotted Blue Lines** Indicate the boundary box (the ends of travel of the axes).
- **Red Lines** Indicate the tool path as it is cut.



Note: The Tool Path display shows the program extents — the furthest points to which the tool will travel while running the program — of the currently loaded G-code file alongside the tool path lines.

- **White Lines** Indicate the preview lines.
- **Yellow Lines** Indicate the jogging moves.

To erase the jogging moves (yellow line) or the tool path (red lines), do one of the following:

- Double-click anywhere in the Tool Path display.
- Select Reset.

7.1.4 Use Conversational Programming

To create simple parts, use the conversational programming feature in PathPilot.

About Conversational Programming	121
Create a Face on a Part	121
Create a Profile on a Part	123
Create a Pocket on a Part	124
Create Hole Locations on a Part (Drill/Tap)	126

Create Threads on a Part	129
Create Text to Engrave on a Part	130
Import a DXF File	131

About Conversational Programming

PathPilot includes G-code generators intended to make simple G-code programs:

- Programs for simple parts.
- Programs for parts made up of a collection of simple features.



Note: For complex parts, or parts with complex shapes, we recommend you use a CAD/CAM program.

The Conversational tab is divided into two sections:

- Parameters common to most operations, like speeds and feeds.



Note: DRO fields that are grayed out are not available for the specific conversational features.

- Parameters specific to each operation, like part geometry.

Create a Face on a Part

Using conversational programming, you can program PathPilot to take multiple cuts — each following the last — on an X/Y plane over a Z range. For information, see "About Facing" (on the next page).

Before You Begin

Before you begin, you must verify that you enter the program values considering the following:

- The area from the rear, left corner of the workpiece to the rear, right corner of the workpiece must be clear of any obstructions from the **Z Start** position to the **Z End** position.
- The top of the workpiece must be free of any workholding devices.
- The value used in the **Z End** DRO field must be such that it is above the workholding device.
- The value used in the **Z Clear** DRO field must be such that it is above any obstruction in the tool path between the end of one pass and the beginning of the next.

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files

To create a face on a part:

1. From the **Conversational** tab, select the **Face** tab.
2. From the **Conversational DROs** group, set the parameters for the facing operation.



Figure 7-15: Conversational DROs on the Face tab.

3. Work through the program-specific DRO fields:
 - a. In the **X Start** DRO field and the **X End** DRO field, type the location of the workpiece edges. We recommend using the rear left corner of the part for the **X Start** value.
 - b. In the **Y Start** DRO field and the **Y End** DRO field, type the location of the workpiece edges. We recommend using the front right corner of the part for the **Y End** value.
 - c. In the **Stepover** DRO field, type the required distance between tool paths. To prevent uncut areas in the spiral corners, we recommend limiting this value to 80% of the tool diameter. For information, see "Facing Reference" (on the next page).
 - d. In the **Z Start** DRO field and the **Z End** DRO field, type the location of the first and last Z passes. For a single Z pass at the location typed in the **Z End** DRO field, type a value of 0 or a full Z range value into the **Depth of Cut** DRO field.
 - e. In the **Depth of Cut** DRO field, type the desired amount of material to remove.



Note: The depth of cut is later adjusted within the Z range so that each pass in the Z range has the same depth (rather than the last Z pass having a short depth of cut).

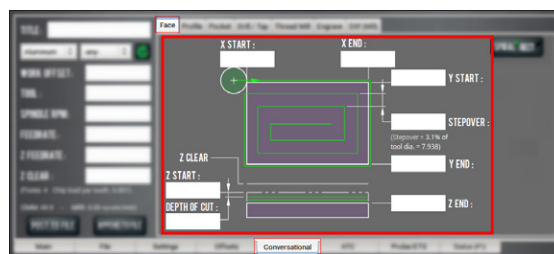


Figure 7-16: Program-specific DROs on the Face tab.

About Facing

Face milling is the process of cutting a surface that's perpendicular to the axis of the cutting tool. A facing program is usually used to cut an accurate, finished top surface on a rough piece of stock material. After a facing program is complete, tool marks remain — creating a fairly flat surface, with microscopic height differences.

Facing in PathPilot

When using a facing routine, each tool pass along the X-/Y-axis begins off to the side of the workpiece to avoid plunging into the workpiece. To compensate for this procedure, PathPilot sets lead-in tool paths outside of the workpiece using the part's work offsets, the tool's diameter, and the predetermined stepover value. PathPilot also adjusts the depth of cut to make sure each tool pass has the same depth, rather than cutting a short depth on the last pass of the program.

During a facing routine, PathPilot does the following:

1. Moves the machine to the predefined G30 position, or the tool change position.
2. If required, performs or requests a tool change.
3. Makes a rapid move in the X and Y direction to the beginning of the workpiece.
4. Makes a rapid move in the Z direction to the predefined Z Clear position.
5. Begins the cut in the X/Y plane at an adjusted Z depth of cut.



Note: The value entered into the Depth of Cut DRO field is adjusted within the Z range (the value entered into the Z End DRO field minus the value entered into the Z Start DRO field).

6. Makes cuts in a rectangular spiral from the workpiece perimeter to the workpiece center.

For information on using conversational programming in PathPilot to face a part, see "Create a Face on a Part" (page 121).

Facing Reference

PathPilot uses the following terms when creating a face on a part in conversational programming:

- **Stepover** Indicates how much space PathPilot creates between each spiral tool path.
- **Z Clear** Indicates the Z location that the tool moves (retracts) to when starting or ending a tool pass.

Create a Profile on a Part

Using conversational programming, you can program PathPilot to take multiple cuts — each following the last — on an X/Y plane over a Z range to form a boss. For information, see "About Profiling" (below).

Before You Begin

Before you begin, you must verify that you enter the program values considering the following:

- The value used in the **Radius** DRO field must be between 0 and either:
 - One half of the boss' narrow width, or
 - The full radii on the long ends of the boss
- The value used in the **Z Clear** DRO field must be set to clear any obstructions between path changes.

To create a profile on a part:

1. From the **Conversational** tab, select the **Profile** tab.
2. From the **Conversational DROs** group, set the parameters for the profiling operation.

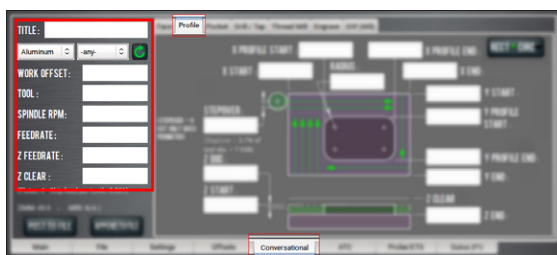


Figure 7-17: Conversational DROs on the Profile tab.

3. Work through the program-specific DRO fields:
 - a. In the **X Start** DRO field and the **X End** DRO field, type the location of the workpiece edges.
 - b. In the **Y Start** DRO field and the **Y End** DRO field, type the location of the workpiece edges.

- c. In the **X Profile Start** DRO field, the **X Profile End** DRO field, the **Y Profile Start** DRO field, and the **Y Profile End** DRO field, type the location of the profile's outer edges.
- d. In the **Stepover** DRO field, type the required distance between tool paths. If you want a single cut in the workpiece (to create a slot), type 0.
- e. In the **Radius** DRO field, type the required radius for the corners of the profile. For no corner radius, type 0.
- f. In the **Z Start** DRO field and the **Z End** DRO field, type the location for the first and last Z passes. For a single Z pass at Z End, type 0 — or a full Z range value — in the **Z DOC** DRO field.
- g. In the **Z DOC** DRO field, type the desired amount of material to remove.



Note: The depth of cut is later adjusted within the Z range so that each pass in the Z range has the same depth (rather than the last Z pass having a short depth of cut).

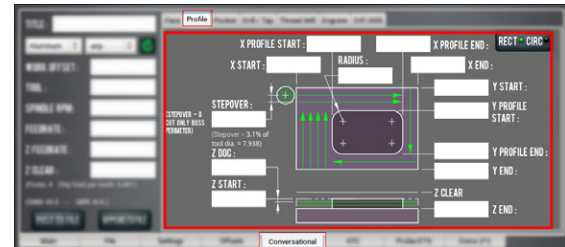


Figure 7-18: Program-specific DROs on the Profile tab.

About Profiling

A profiling program is usually used to create a circular or rectangular boss within a larger piece of stock material. The outer bound of the area is the stock material's perimeter. The inner bound of the area is the boss' perimeter.

Profiling in PathPilot

When using a profile routine, each tool pass along the X-/Y-axis begins off to the side of the workpiece to avoid plunging into the workpiece. To compensate for this procedure, PathPilot sets lead-in tool paths outside of the workpiece using the part's work offsets, the tool's diameter, and the predetermined stepover value. PathPilot also adjusts the depth

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files

of cut to make sure each tool pass has the same depth, rather than cutting a short depth on the last pass of the program. When you're creating a profile on a part using conversational programming, PathPilot does the following in the order listed:

1. Retracts the tool to the **Z Clear** position.



Note: The first Z pass cuts at **Z Start** minus Depth of Cut adjusted.

2. Makes a rapid movement to the beginning of the section.
3. If required, makes a tool path around the perimeter of the boss to cut the programmed radii.



Note: Radius cuts use an adjusted feed rate to compensate for the difference between the tool's control point rate (at the tool center) and the actual rate at the radius surface.

4. Repeats Steps 1-3 for each predefined **Z Depth of Cut**.



Note: The last Z pass will cut at the **Z End** location.

For information on using conversational programming in PathPilot to create a profile, see "Create a Profile on a Part" (on the previous page).

Profiling Reference

PathPilot uses the following terms when creating a profile on a part in conversational programming:

- **Stepover** Indicates the tool path offset between section sweeps.
- **Z Clear** Indicates the Z location the tool moves to or retracts to when starting or ending a section change, section sweep, or Z pass.

Create a Pocket on a Part

Using conversational programming, you can program PathPilot to take multiple cuts — each following the last — on an X/Y plane over a Z range to form a circular or rectangular pocket. For information, see "About Pockets" (on the next page).

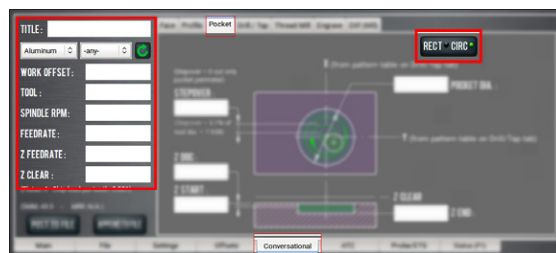
Before You Begin

Before you begin, you must verify that you enter the program values considering the following:

- The value used in the **Radius** DRO field must be between 0 and either:
 - One half of the pocket's narrow width, or
 - The full radii on the long ends of the pocket

To create a circular pocket on a part:

1. From the **Conversational** tab, select the **Pocket** tab.
2. From the **Conversational DROs** group, set the parameters for the pocket operation.



3. Work through the program-specific DRO fields:
 - a. In the **X Center** DRO field and the **Y Center** DRO field, type the location of the pocket's center.
 - b. In the **Pocket Dia.** DRO field, type the required diameter for the pocket.



Note: The radius of the tool is used to set the tool path diameter.

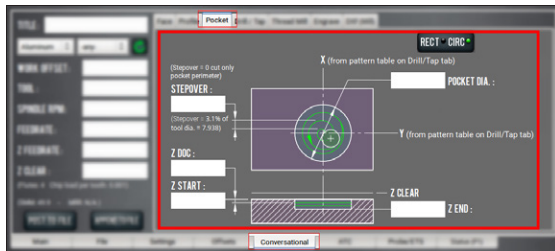
- c. In the **Stepover** DRO field, type the required distance between each rotation of the spiral cut. For a single cut around the inside perimeter of the pocket (to create a slot), type 0.
- d. In the **Z Start** DRO field and the **Z End** DRO field, type the location of the first and last Z passes. For a single Z pass at the location typed in the **Z End** DRO field, type a value of 0 or a full Z range value into the **Depth of Cut** DRO field.

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files

- e. In the **Z DOC** DRO field, type the desired amount of material to remove.

Note: The depth of cut is later adjusted within the Z range so that each pass in the Z range has the same depth (rather than the last Z pass having a short depth of cut).



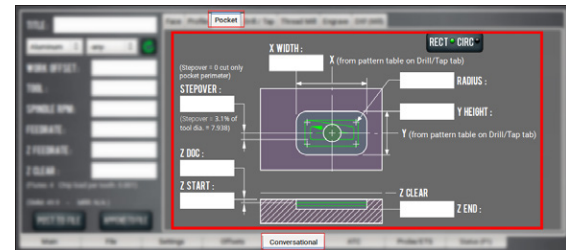
To create a rectangular pocket on a part:

1. From the **Conversational** tab, select the **Pocket** tab.
2. From the **Conversational DROs** group, set the parameters for the pocket operation.



3. Work through the program-specific DRO fields:
 - a. In the **X Start** DRO field, the **X End** DRO field, the **Y Start** DRO field, and the **Y End** DRO field, type the location of the pocket edges.
 - b. In the **Radius** DRO field, type the required radius for the corners of the pocket. For no corner radius, type 0.
 - c. In the **Stepover** DRO field, type the required distance between adjacent tool paths. For a single cut around the inside perimeter of the pocket (to create a slot), type 0.
 - d. In the **Z Start** DRO field and the **Z End** DRO field, type the location of the first and last Z passes. For a single Z pass at the location typed in the **Z End** DRO field, type a value of 0 or a full Z range value into the **Depth of Cut** DRO field.
 - e. In the **Z DOC** DRO field, type the desired amount of material to remove.

Note: The depth of cut is later adjusted within the Z range so that each pass in the Z range has the same depth (rather than the last Z pass having a short depth of cut).



About Pockets

A pocket program is usually used to remove a large amount of material from a part.

Creating Pockets in PathPilot

For more information about creating a pocket on a part using conversational programming, see of the following sections, depending on the shape of the pocket:

- "About Circular Pockets" (below)
- "About Rectangular Pockets" (on the next page)

For information on using conversational programming in PathPilot to make a pocket on a part, see "Create a Pocket on a Part" (on the previous page).

About Circular Pockets

PathPilot does one of the following, depending on the diameter of the tool:

- **Tool Diameter Larger Than Pocket Diameter**
PathPilot displays an error and does not create any G-code. You must select a different tool or edit the diameter of the pocket.
- **Tool Diameter Just Small Enough to Fit Within Pocket Diameter** PathPilot does the following in the order listed:
 1. Uses a straight Z plunge into the pocket center. You must use a center-cutting end mill.
 2. Makes a single pass around the perimeter of the pocket at the adjusted Z depth of cut.
 3. Continues to make single passes around the perimeter of the pocket.
- **Pocket Diameter More Than Two Times Tool Diameter** PathPilot does the following in the order

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files

listed:

1. Uses a helical entry into the pocket center.
2. Makes a hole that is two times the diameter of the tool diameter in the pocket center.
3. Makes a spiral cut out from the pocket center to the pocket diameter.
4. Makes a cut around the perimeter of the pocket.

About Rectangular Pockets

PathPilot does one of the following, depending on the diameter of the tool:

- **Tool Diameter Larger Than Pocket Width** PathPilot displays an error and does not create any G-code. You must select a different tool or edit the width of the pocket.
- **Tool Diameter Just Small Enough to Fit Within Pocket Parameters** PathPilot does the following in the order listed:
 1. Uses a straight Z plunge into the pocket center. You must use a center-cutting end mill.
 2. Makes a single pass around the perimeter of the pocket at the adjusted Z depth of cut.
 3. Continues to make single passes around the perimeter of the pocket.
- **Length of Pocket More Than Two Times Diameter of Tool** PathPilot uses a linear ramp entry.
- **Pocket Parameters More Than Two Times Diameter of Tool** PathPilot uses a helical entry.

Create Hole Locations on a Part (Drill/Tap)

Using conversational programming, you can program PathPilot to make multiple holes on a part. For information, see "About Drilling and Tapping" (on the next page).

Before You Begin

Before you begin, you must verify that you enter the program values considering the following:

- In the **Conversational DROs** group, the value in the **Z Clear** DRO field must be set to clear any obstructions between hole changes.

To make a specific hole pattern of evenly spaced holes around a circumference (also known as a bolt pattern):

1. From the **Conversational** tab, select the **Drill/Tap** tab.

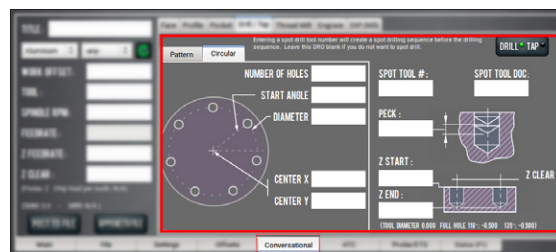


Figure 7-19: Drill/Tap tab on the Conversational tab.

2. From the **Drill/Tap** tab, select the **Circular** tab.
3. In the **Number of Holes** DRO field, type the number of holes (greater than 0) required for the pattern.
4. In the **Start Angle** DRO field, type the value of the angle from angle 0 (from -90 to 90).
5. In the **Diameter** DRO field, type the size of the circular pattern (as defined by a line through the center point of each hole).
6. In the **Center X** DRO field and the **Center Y** DRO field, type the location for the center of the hole.
7. Depending on if you're drilling or tapping the holes, do one of the following:
 - Go to "Create a Drilling Sequence" (on the next page).
 - Go to "Create a Tapping Sequence" (page 128).

Use the Location table to make a list of X and Y locations for each hole using the same tool, the same Z location, and the same values in the Conversational DROs group.



Note: You can create holes using different tools or different parameters. You must first post the first group of hole locations, enter the second group of hole locations, and then append the second group to the existing posted file.

To make a hole pattern based on X and Y locations on a part:

1. From the **Conversational** tab, select the **Drill/Tap** tab.

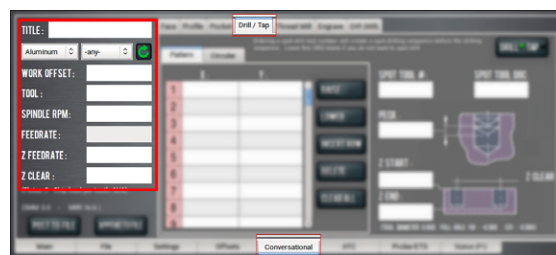


Figure 7-20: Drill/Tap tab on the Conversational tab.

2. From the **Drill/Tap** tab, select the **Pattern** tab.

3. In the **Location** table, select the row, then select the cell to edit.
Holes indicated in the **Location** table are completed from top to bottom.
4. Depending on if you're drilling or tapping the holes, do one of the following:
 - Go to "Create a Drilling Sequence" (below).
 - Go to "Create a Tapping Sequence" (on the next page).

Tips

- To rearrange the row order, select a row, and then select **Raise** or **Lower**.
- To clear all values in the table, select **Clear All**.
- To make sure that the value is a valid number, leave the cell. If the value isn't a valid number, it's erased, and an error displays on the **Status** tab.
- Before posting the file, make sure that there are none of the following:
 - X values without a Y value
 - Y values without an X value
 - An empty row before the last row with values

About Drilling and Tapping

A drilling and tapping program is used to create a series of holes in defined locations on a part.

Drilling and Tapping in PathPilot

PathPilot has the following options to define the locations:

- **Pattern** Use X and Y locations to make a list of hole locations.
- **Circular** Use a circumference to make a specific pattern of evenly spaced holes.

For information on using conversational programming in PathPilot to drill and tap holes, see "Create Hole Locations on a Part (Drill/Tap)" (on the previous page).

During a drilling routine, PathPilot uses one of the following canned G-code cycles, depending on the entries in each DRO field:

- **G81** Drill
- **G82** Drill with dwell
- **G83** Drill with peck



Note: The features can't be combined, because peck cancels dwell.

When using a tapping routine, PathPilot uses the G84 canned G-code cycle. G84 is similar to G81, but it commands a spindle reverse once it gets to the bottom of the hole.

It's important that the Z Feedrate matches the spindle RPM and tap pitch, so the rate is calculated from the Pitch and RPM DRO entries. The result is displayed in the Z Feedrate DRO (in the left panel) after the **Enter** key is selected in one of the RPM, Pitch, or TPU DRO fields.



Note: An auto-reversing tapping head typically uses a drilling cycle.

Create a Drilling Sequence

The Drill tab uses one of the following canned G8x cycles to drill a hole at each identified location:

- **G81** Drill
- **G82** Drill with dwell
- **G83** Drill with peck



Note: The features can't be combined, because peck cancels dwell.

Hole depth is usually defined as the full diameter portion of the hole, so you may need to consider the Z length from the drill point to the corner.

1. In the **Spot Tool #** DRO field, type the number of the spot drill.

If a valid tool number is used in the **Spot Tool #** DRO field, PathPilot makes a spot drilling sequence before the drilling sequence. In the spot drilling sequence, PathPilot uses the values indicated in the **Feedrate** DRO field, the **Spindle RPM** DRO field, and the **Z Clear** DRO field.



Note: To skip a spot drilling sequence, leave the **Spot Tool #** DRO field blank.

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files

2. In the **Spot Tool DOC** DRO field, type the depth of cut for the spot drilling sequence.



Note: To skip a spot drilling sequence, leave the **Spot Tool DOC** DRO field blank.

3. In the **Peck** DRO field, type the distance for each peck.



Note: Any entry greater than **0** typed in the **Peck** DRO field replaces G81 with G83 in the G-code. For information, see "Drilling and Tapping Reference" (below).

4. Set the parameters for the hole in the Z range:
 - a. In the **Z Start** DRO field, type the location for the first Z pass.
 - b. In the **Z End** DRO field, type the location for the last Z pass.

Create a Tapping Sequence

The Tap tab uses the G84 canned cycle — it's similar to the G81 drill cycle, but it commands a spindle reverse once it reaches the bottom of the hole.



Note: If you're using an auto-reversing tapping head, use a drilling sequence. Go to "Create a Drilling Sequence" (on the previous page).

1. In the **Dwell** DRO field, type the time — in seconds — for the tool to pause at the bottom of the hole before retracting.

A dwell gives the tool time to completely cut the bottom of the hole.



Note: Any entry greater than **0** typed in the **Dwell** DRO field replaces G81 with G82 in the G-code — unless there is an entry greater than **0** in the **Peck** DRO field.

2. Set the parameters for the threads: In the **Pitch (In)** DRO field or the **Threads/In** DRO field, type either the required pitch or the threads per inch.



Note: The **Pitch (In)** DRO field and the **Threads/In** DRO field are linked — after you type a value in one and press **Enter** on the keyboard, the other is auto-filled.

3. In the **Conversational DROs** group, make sure that the value in the **Z Feedrate** DRO field is the same as the value that you set in Step 2.
4. Set the parameters for the hole in the Z range:
 - a. In the **Z Start** DRO field, type the location for the first Z pass.
 - b. In the **Z End** DRO field, type the location for the last Z pass.

Drilling and Tapping Reference

PathPilot uses the following terms when drilling and tapping on a part in conversational programming:

- **Start Angle** Specifies the angle from angle 0. Angle 0 is a base (horizontal) line from the center point going right (east) to the circumference. The angle from the base line can be:
 - Positive or negative
 - Up to 90 degrees (or -90 degrees)

A negative angle produces a clockwise rotation; a positive angle produces a counterclockwise rotation.
 - Rotates the pattern either clockwise or counterclockwise

For example, to create a hex pattern with flats on the top and bottom, use a value of 0 in the Start Angle DRO field. To create a hex pattern with flats on the left and right sides, use a value of 30 (or -30) in the Start Angle DRO field.
- **Peck** The value isn't adjusted: the G83 routine feeds at the Z Feedrate, starting from Z Clear down to the Peck distance, then rapid retracts to Z Clear, and rapid returns to start the next Peck.



Note: The first and last peck will likely be shorter than the value typed into the Peck DRO field.

Create Threads on a Part

Using conversational programming, you can program PathPilot to take helical tool paths around a boss or inside a hole to create external or internal threads. For information, see "About Thread Milling" (below).

Before You Begin

Before you begin, you must verify that you enter the program values considering the following:

- The auto-filled DRO field values assume a full-form threaded tool. If you're using a fine-point threaded tool to cut coarse threads, you must modify the root diameter to account for the tool's smaller nose radius.
- The value used in the **Z Clear** DRO field must be such that it can clear any blockages in the path between the end of one Z pass and the beginning of the next.

To create threads on a part:

1. From the **Conversational** tab, select the **Thread Mill** tab.
2. From the **Conversational DROs** group, set the parameters for the thread milling operation.

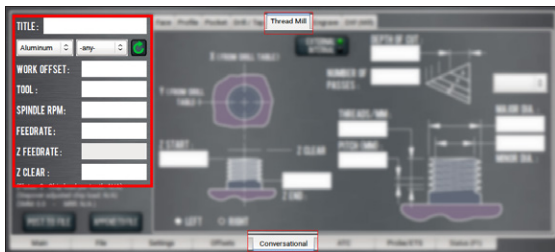


Figure 7-21: Conversational DROs on the Thread Mill tab.

3. Depending on the type of threads, do one of the following:
 - For external threading (creating threads on a boss, for example), select **External**.
 - For internal threading (creating threads inside a hole, for example), select **Internal**.
4. Work through the program-specific DRO fields:
 - a. From the **Quick Reference** drop-down, select the thread size.
The **Threads/In** DRO field, **Pitch (In)** DRO field, **Major Dia.** DRO field, and **Minor Dia.** DRO field auto-fill.

Note: The threads listed follow the current unit setting: either inches (G20) or millimeters (G21).

- b. In the **Z Start** DRO field, type the location of the first Z pass (where you want the thread to start).
- c. In the **Z End** DRO field, type the location of the last Z pass (where you want the thread to end).

Note: The tool actually goes beyond the value entered in the **Z End** DRO field, due to the cutting tip width and the Z component of the compound feed angle and thread depth.

- d. In the **Depth of Cut** DRO field or the **Number of Passes** DRO field, type a value to represent the amount of material to remove in each helical pass. For information, see "Thread Milling Reference" (on the next page).

Note: The **Depth of Cut** DRO field and the **Number of Passes** DRO field are linked — after you type a value in one and press **Enter** on the keyboard, the other is auto-filled.

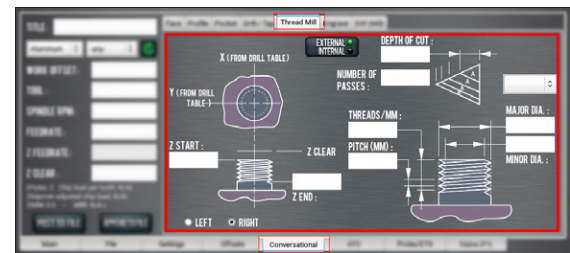


Figure 7-22: Program-specific DROs on the Thread Mill tab.

About Thread Milling

Thread milling is used to make helical tool paths on a part — either externally, like on a boss, or internally, like in a hole. The right-handed threads are based on pitch, diameter, and length.

Thread Milling in PathPilot

For information on using conversational programming in PathPilot to do thread milling, see "Create Threads on a Part" (above).

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files

Thread Milling Reference

PathPilot uses the following terms when creating a thread mill on a part using conversational programming:

- **Major Dia. and Minor Dia.** Set the start and end diameter of the thread peak and valley.
- **Depth of Cut** Sets the amount of material cut in each helical pass — the value is the distance (the change in radius) the tool is fed on the first pass. This first pass cuts a triangular area which is related to the chip load. Subsequent cut depths are set to cut the same amount of area, so the linear feed gets smaller for each pass. The tool is also fed in on a compound angle of 30 degrees, keeping the cuts to one face of the tool.



Note: The Depth of Cut DRO field and the Number of Passes DRO field are linked — after you type a value in one and press **Enter** on the keyboard, the other is auto-filled.

- **Z Clear** The location the tool moves or retracts to when starting or ending a Z pass.

Create Text to Engrave on a Part

Using conversational programming, you can program PathPilot to engrave a single line of text on a part. For example, you could use this feature to engrave True Type stick or outline fonts into things like simple plaques, control panels, or data plates. For information, see "About Engraving" (on the next page).

To create an engraving sequence on a part:

1. From the **Conversational** tab, select the **Engrave** tab.
2. From the **Conversational DROs** group, set the parameters for the engraving operation.

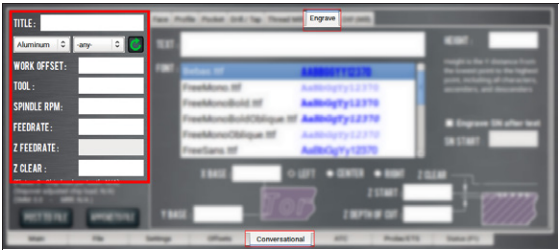


Figure 7-23: Conversational DROs on the Engrave tab.

3. Work through the program-specific DRO fields:
 - a. In the **Text** DRO field, type the desired text to engrave.

The text appears in the **Preview** window.

- b. From the **Font** list, select the desired font for the engraved text.



Note: To search the **Font** list, select a font and begin typing the font's name. PathPilot scrolls to the result.

The **Preview** window updates to display the font selected.



Note: You can add True Type font files to the PathPilot controller. For information, see "Transfer Files to and From the Controller" (page 174).

- c. Use the **Alignment** radio buttons to select the desired alignment of the text: either **Left**, **Center**, or **Right**. The **Preview** window updates to display the font selected.
- d. In the **Height** DRO field, type the distance in the Y direction from the top of the text to the bottom of the text.

PathPilot uses the height value, along with font data, to calculate scale for character paths in the G-code program.



Note: The value typed in the **Height** DRO field includes ascenders and descenders, but no the tool cutting diameter. For a more accurate value, subtract the diameter from the overall height.

- e. In the **X Base** DRO field and the **Y Base** DRO field, type the location of the left side of the first character's baseline.



Note: If any characters in the text have descenders, like **y** or **g**, they extend below the baseline.

- f. In the **Z Start** DRO field, type the location of the surface on which to engrave.

- g. In the **Z Depth of Cut** DRO field, type the desired depth the that the cutting tool is fed into the workpiece.
- h. In the **Z Clear** DRO field, type the value for the tool to move or retract to — in the **Z** direction — at the start and end of the engraving sequence and between characters.

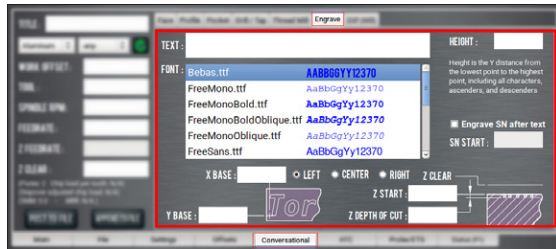


Figure 7-24: Program DROs on the Engrave tab.

About Engraving

Engraving is used to engrave a single line of text cut in a single horizontal pass along the X-axis of a part.

Import a DXF File

You can import a .dxf file (Drawing Exchange Format) into PathPilot to generate G-code, which can then cut the shape (or shapes) described in the .dxf file. For example, you could use this feature to engrave logos or artwork.

1. From the **Conversational** tab, select the **DXF** tab.

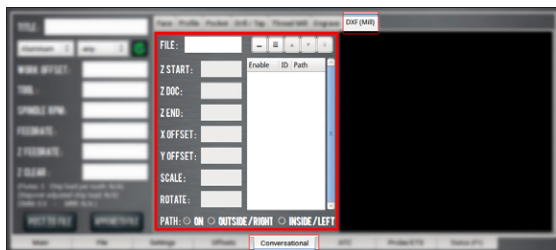


Figure 7-25: DXF tab on the Conversational tab.

2. Select the **File** DRO field.
The **File Selector** dialog box opens.
3. Select the .dxf file, and then select **Open**.
4. The shapes from the selected file are loaded into the **Preview** window.



Note: The .dxf file must already be transferred to the PathPilot controller. For information, see "Transfer Files to and From the Controller" (page 174).

5. In the **X Offset** DRO field and the **Y Offset** DRO field, type the offset value added in the **XY** direction from the bottom left corner of the .dxf drawing.
6. In the **Scale** DRO field, type the scale factor for the drawing. The value typed in the **Scale** DRO field is used as a multiplier for the .dxf dimensions, and is used for the entire drawing.



EXAMPLE

If you type 1.0 in the **Scale** DRO field, the .dxf is scaled at 100%.

If you type 2.0 in the **Scale** DRO field, the .dxf is scaled at 200%.

7. In the **Rotate** DRO field, type the rotation angle in degrees.
The rotation angle is applied around the Z-axis of the drawing's origin.
8. Select one of the following to set the cutter compensation to be applied to the tool path:
 - **On:** The tool moves along the path.
 - **Outside / Right:** Offsets the tool path right of the drawing path, seen from the direction where the tool enters the path.
 - **Inside / Left:** The opposite of **Outside / Right**.

Working with Layers and Shapes

The .dxf file contains shapes grouped into layers. In the **Shape Selection** tree view window, you can enable or disable individual layers and complete layers. You can select shapes either from the tree view window or in the **Preview** window.

Change the Layer or Shape Cut Order

- Use the **Up Arrow** and **Down Arrow** buttons above the **Shape Selection** tree view window.
Shapes or layers higher in the tree view window are cut earlier than those below it. The order in which the shapes are cut is the same as the order of the enabled shapes in the tree view window and the cyan path in the **Preview** window.

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files



Note: If a layer is selected, the whole layer is moved up or down. Shapes can't be moved between layers.

Adjust the Tree View Window

- Use the **Fold** and **Unfold** buttons to collapse and expand the layer and shape tree in the tree view window.

Working in the Preview Window

The **Preview** window uses the following colors:

- **Cyan** Selected paths
- **Gray** Disabled paths
- **White** Drawing path
- **Magenta** Cut path
- **Dark Cyan Stippled Line** Tool path between cuts
- The coordinates use the following colors:
 - **Red** X-axis
 - **Green** Y-axis
 - **Blue** Z-axis

7.2 MACHINE SETTINGS AND ACCESSORIES

Before running a G-code program, you must first make sure that the machine settings are properly configured.

7.2.1 Enable an Internet Connection	133
7.2.2 Change the Network Name	134
7.2.3 Select the Spindle Type	134
7.2.4 Change the Screen Orientation	134
7.2.5 Specify the Tool Change Method	136
7.2.6 Disable Hard Stop Referencing	136
7.2.7 Limit G30 Moves	137
7.2.8 Enable the On-Screen Keyboard	137
7.2.9 Enable the USB M-Code I/O Interface Kit	138
7.2.10 Enable Tooltips	138
7.2.11 Enable the Door Lock Switch Kit	138
7.2.12 Enable Feeds and Speeds Suggestions in Conversational Routines	139
7.2.13 Specify Probing and Tool Measuring Options	139
7.2.14 Use the RapidTurn Interface	139
7.2.15 Specify the 4th Axis Rotary Type	139
7.2.16 Use a USB Camera	140

7.2.1 Enable an Internet Connection

If desired, you can enable an internet connection on your PathPilot controller. An internet connection allows you to receive automatic PathPilot updates and transfer files with PathPilot HUB instead of a USB drive.

To enable an internet connection:

1. From the PathPilot interface, on the **Status** tab, select **Internet**.



Figure 7-26: Internet button on the Settings tab.

The **Network Configuration** dialog box displays.

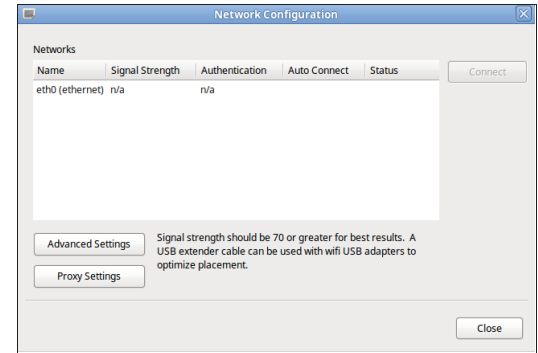


Figure 7-27: Network Configuration dialog box.

2. From the **Network Configuration** dialog box, in the **Networks** list, select the network you want to use. Then, select **Connect**.



Note: Wi-Fi connection signal strengths are indicated on a scale of 0 to 100, with 100 being the strongest. PathPilot continually refreshes the signal levels to help you find the best placement for your Wi-Fi network adapter. Ethernet connections are indicated by a prefix in the following format: `eth[NUMBER]`. For example, `eth1`.

The PathPilot operating system connects to the internet using the network you specified. It continues to detect and connect to the Wi-Fi network, even after power cycles.

Enable Automatic Updates



Note: Automatic updates require an internet connection. If you haven't yet enabled it, go to "Enable an Internet Connection" (above).

If desired, you can enable automatic updates for PathPilot. To enable automatic updates:

1. From the PathPilot interface, on the **Status** tab, select **Update**.

The **Software Update** dialog box displays.

7: PATHPILOT TOOLS AND FEATURES

7.2 Machine Settings and Accessories

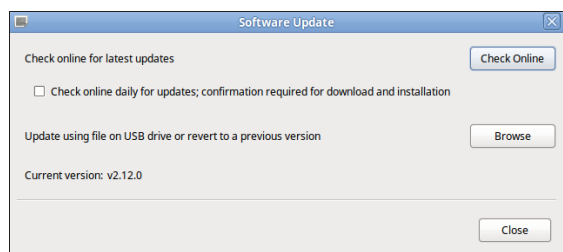


Figure 7-28: Software Update dialog box.

- From the **Software Update** dialog box, select the **Check online daily for updates; confirmation required for download and installation** checkbox.
- Select **Close**.
When future updates are available, the **Status** tab displays a notification.

7.2.2 Change the Network Name

If you're connected to a network using either the Ethernet jack or the (optional) **Wireless Network Adapter (PN 38207)**, the PathPilot controller appears on your network as **network-attached storage**. The default network name of the controller is **TORMACHPCNC**.

To change the network name:

- From the **Network Name** field, type a new network name.

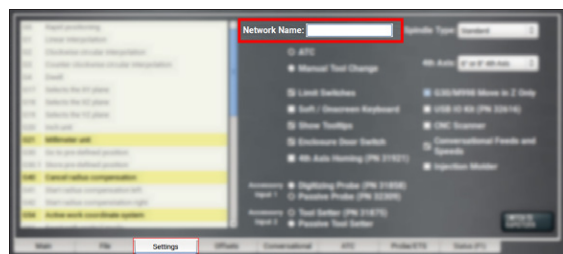


Figure 7-29: Network Name field on the Settings tab.



Note: The network name must be unique within your network.

- Select the **Enter** key.
- For the change to take effect, you must restart the controller.

7.2.3 Select the Spindle Type

If you have an additional spindle (separate from the standard spindle), you must first select it in PathPilot.

To select the spindle type:

- From the **Settings** tab, from the **Spindle Type** drop-down, select the appropriate spindle option.

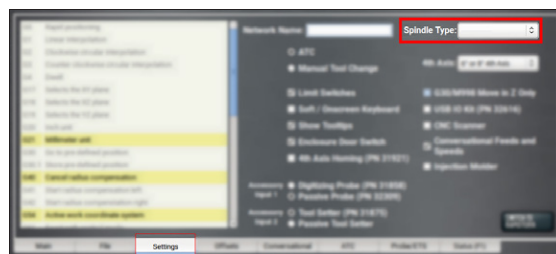


Figure 7-30: Spindle Type field on the Settings tab.

7.2.4 Change the Screen Orientation

A vertical orientation for 1920 × 1080 monitors is supported in PathPilot v2.10.0 and later. For more information on the portrait layout, go to "About Portrait Screen Layout" (on the next page).

To change the screen orientation:

- From the PathPilot interface, on the **Settings** tab, select **Portrait** from the **Layout** drop-down menu. Restart the controller.

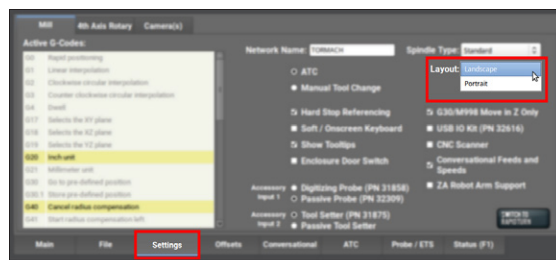


Figure 7-31: Layout drop-down menu on the Settings tab.

- Rotate the monitor to the portrait orientation. You can rotate it either left or right, depending on what's easier for your setup.

- While the controller is restarting, specify which direction you've rotated the monitor. Select **Apply**. If the result is unexpected, click **Restore Previous Configuration** on the confirmation dialog and choose a rotation direction again.

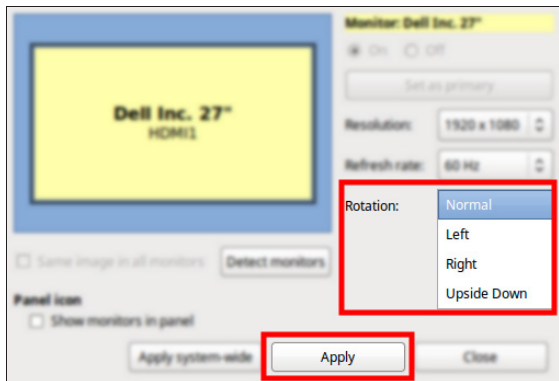


Figure 7-32: Monitor configuration dialog box.

The controller restarts in portrait layout.

About Portrait Screen Layout

Portrait layout provides some key advantages:

- A larger tool path window that's always visible at the top of the screen, regardless of which tab you have active.

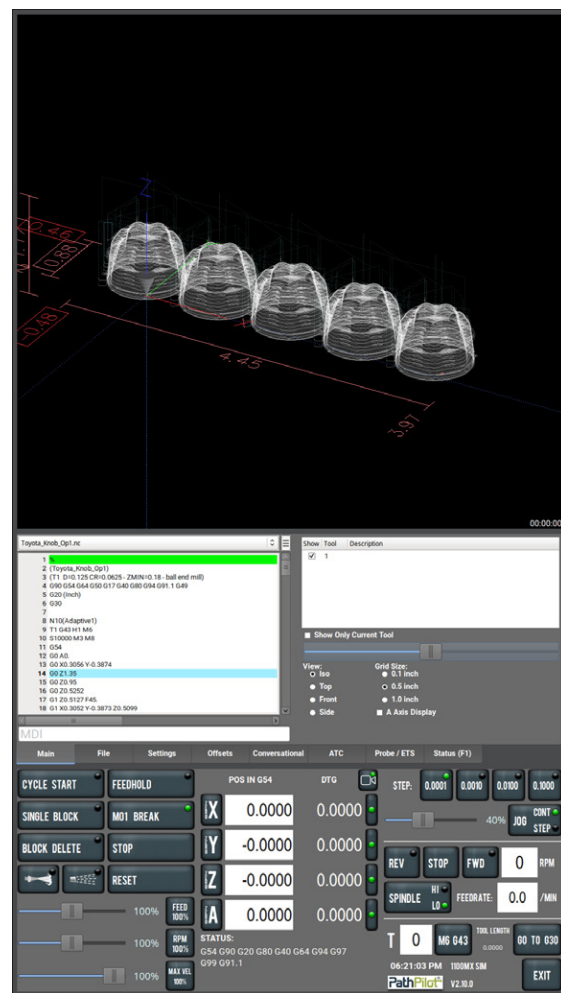


Figure 7-33: Tool Path window in portrait screen layout.

- A wider G-code window to more easily read the loaded G-code file and, if enabled, line numbers.
- The tool path window's view options are always visible for much easier access.

7: PATHPILOT TOOLS AND FEATURES
7.2 Machine Settings and Accessories

- When browsing G-code files using the File tab, file previews display on the top portion of the screen.

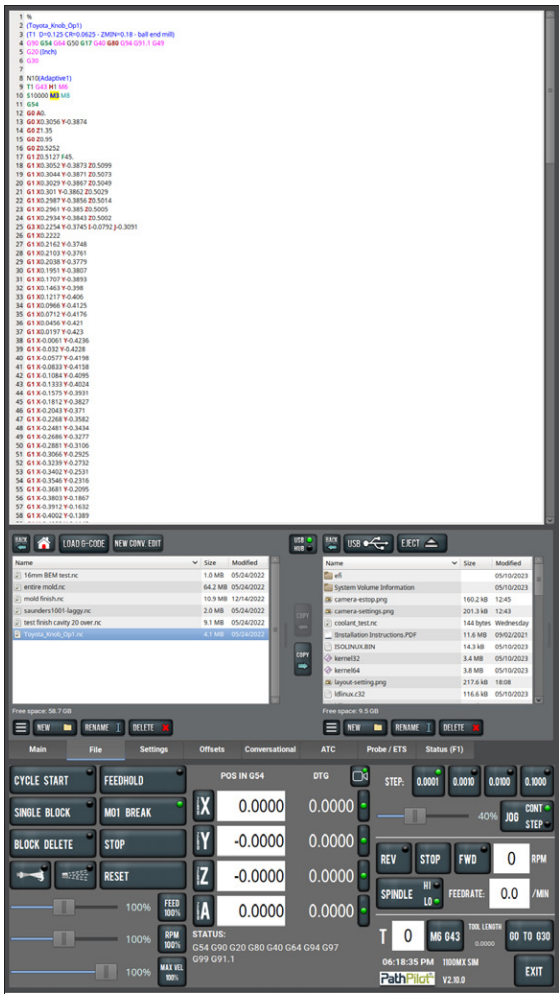


Figure 7-34: File tab G-code preview in portrait screen layout.

7.2.5 Specify the Tool Change Method

When PathPilot finds an M06 command in a G-code program, it has different behaviors depending on the specified tool change method.

To specify the tool change method:

- From the Settings tab, select the appropriate tool change method for your machine.

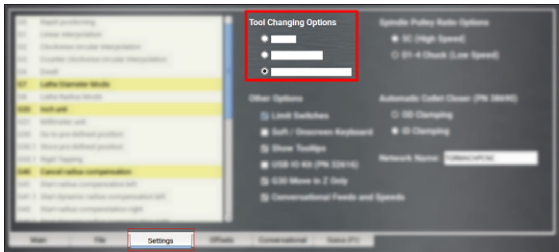


Figure 7-35: Tool change method options on the Settings tab.

About Automatic Tool Changes

If you're using an Automatic Tool Changer (ATC) to make tool changes, PathPilot does the following:

- Looks for an ATC.
- When PathPilot finds a Txx M06 command in the G-code program, the ATC loads the specified tool into the spindle.

About Manual Tool Changes

If you're making manual tool changes, PathPilot pauses when it finds an M06 command in the G-code program. While it's paused, PathPilot does the following:

- The Cycle Start button flashes.
- The Tool Path display shows the requested tool number.

7.2.6 Disable Hard Stop Referencing

To provide a temporary workaround for a malfunctioning limit switch circuit, you can disable the limit switches.

Note: By default, the Hard Stop Referencing checkbox is selected.

To disable hard stop referencing:

- From the Settings tab, clear the Hard Stop Referencing checkbox.

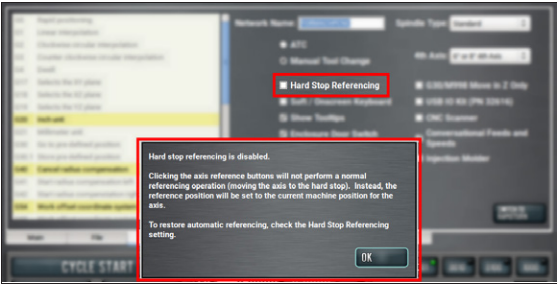


Figure 7-36: Hard Stop Referencing checkbox on the Status tab.

2. Select **OK**.

The machine completes a unique referencing procedure after selecting the axis reference buttons: rather than moving each axis to the end of its travel, the reference position is set as the machine's current position.



Tip! This is useful for troubleshooting, because you're now able to move the axis.

About Limit Switches

In the PathPilot interface, on the Settings tab, the Hard Stop Referencing checkbox is selected by default.

If the checkbox is cleared, the machine completes a unique referencing procedure after selecting Ref X, Ref Y, Ref Z, and Ref A: rather than moving each axis to the end of its travel, the reference position is set as the machine's current position. This is useful for troubleshooting: if the limit switches are disabled, you're able to move the axis off of its limit switch.

7.2.7 Limit G30 Moves

You can limit G30 moves so that only the Z-axis moves. For information, see "About G30" (page 158).

To limit G30 moves:

- From the **Settings** tab, select **G30/M998 Move in Z Only**.

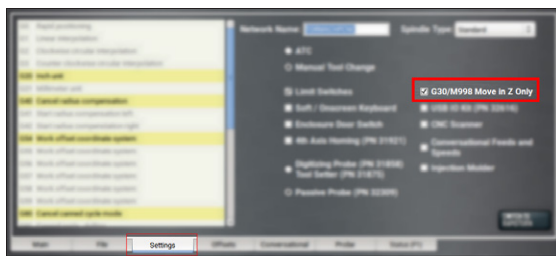


Figure 7-37: Settings tab.

About G30

A G30 command in a G-code program moves the machine to a preset position. For more information on setting a G30 position, see "Use a G30 Position" (page 158).

Use a G30 move to start a coordinated movement of the axes. You can limit the movement to only the Z-axis. For information, see "Limit G30 Moves" (above).



Tip! It's useful to program a G30 move right before a tool change so that the machine can jog to a safe tool change position.

7.2.8 Enable the On-Screen Keyboard

If you have an (optional) **Touch Screen Kit (PN 35575)**, you can use a soft keyboard to type information in the PathPilot interface. For information, see "About Soft Keyboards" (below).

To enable and use the soft (on-screen) keyboard:

1. From the **Settings** tab, select **Soft / On-Screen Keyboard**.

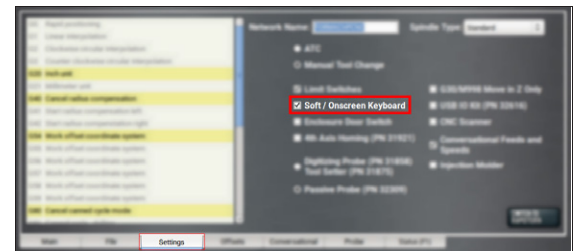


Figure 7-38: Settings tab.

2. To resize the keyboard, select a corner of the keyboard and drag.
3. To reposition the keyboard, select the **Anchor** key and drag the keyboard anywhere on the screen.



4. To close the keyboard, select the **X** key.



About Soft Keyboards

If you enabled a soft keyboard (on-screen keyboard) in the PathPilot interface to use with an optional touch screen or operator console, a keyboard opens when you select any field where keyboard input is required.

The keyboard displays a wide range of keys: both uppercase and lowercase, symbols, arrow keys, caps lock, backspace and delete, and more.

7: PATHPILOT TOOLS AND FEATURES

7.2 Machine Settings and Accessories



Figure 7-39: Soft (on-screen) keyboard.

7.2.9 Enable the USB M-Code I/O Interface Kit

If you have a [USB M-Code I/O Interface Kit \(PN 32616\)](#), you must first enable it in the PathPilot interface. To enable the USB M-Code I/O Interface Kit:

- From the **Settings** tab, select **USB IO Kit (PN 32616)**.

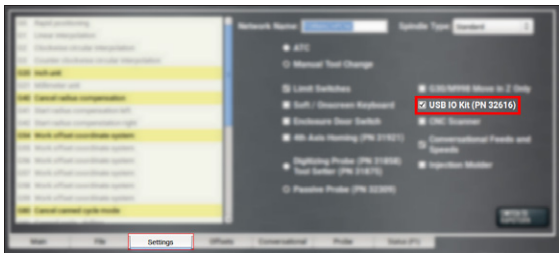


Figure 7-40: Settings tab.

7.2.10 Enable Tooltips

PathPilot displays expandable tooltips for many areas of the interface. Hovering over an item, like a DRO field or a button, displays helpful information about the item. To enable or disable tooltips:

1. From the Settings tab, select or clear **Show Tooltips**.

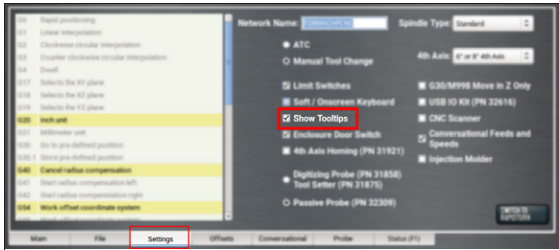


Figure 7-41: Show Tooltips checkbox.

Note: If you disable the tooltips, you can still display them for specific items. Hover over an area of the interface, and select the Shift key on the keyboard.

7.2.11 Enable the Door Lock Switch Kit

If you have a Door Lock Switch Kit, you must first enable it in PathPilot.

To enable the Door Lock Switch Kit:

1. On the **Settings** tab, select **Enclosure Door Switch**.

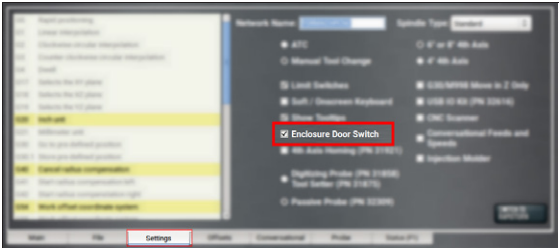


Figure 7-42: Settings tab.

On the **Status** tab, the **Door Locked / Open** LEDs display.

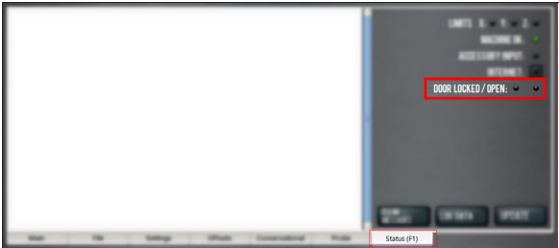


Figure 7-43: Status tab.

2. Reference the machine: select **Ref Z**, **Ref X**, and **Ref Y**.
3. Open the enclosure doors.
4. From the PathPilot interface, on the **Status** tab, make sure that the **Door Open** LED is on, and the **Door Locked** LED is off.

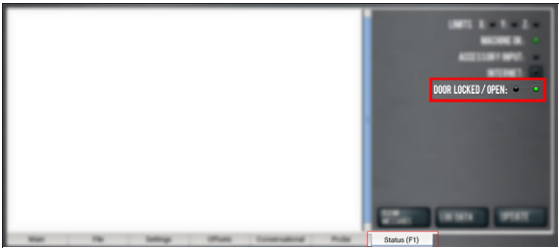


Figure 7-44: Door Open LED on the Status tab.

7: PATHPILOT TOOLS AND FEATURES

7.2 Machine Settings and Accessories

5. Close the enclosure doors and verify that the **Door Open** LED is off. Then, push in the Emergency Stop button on the operator box.
The doors lock, and the **Door Locked** LED comes on.
6. From the PathPilot interface, on the **Status** tab, make sure that the **Door Open** LED is off.
7. Unlock the enclosure doors: twist out the Emergency Stop button and press the Reset button on the operator box.
The doors unlock.

7.2.12 Enable Feeds and Speeds Suggestions in Conversational Routines

You can use PathPilot to automatically calculate feeds and speeds. For more information, see "Use Feeds and Speeds Suggestions" (page 160).

- From the **Settings** tab, select **Conversational Feeds and Speeds**.

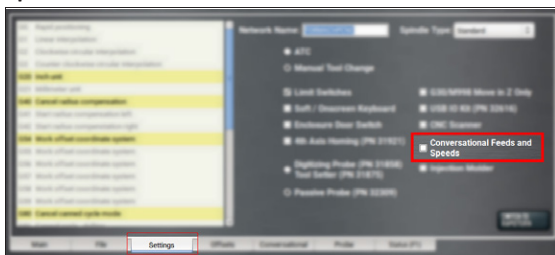


Figure 7-45: Settings tab.

7.2.13 Specify Probing and Tool Measuring Options

If you have any of the following accessories, you must first specify which you're using in the PathPilot interface:

- Active Probe (PN 31858)
- Passive Probe (PN 32309)
- Electronic Tool Setter (PN 31875)

To specify a probe or a tool setter:

- From the **Settings** tab, select the correct probing or tool measuring options for both **Accessory Input 1** and **Accessory Input 2**.

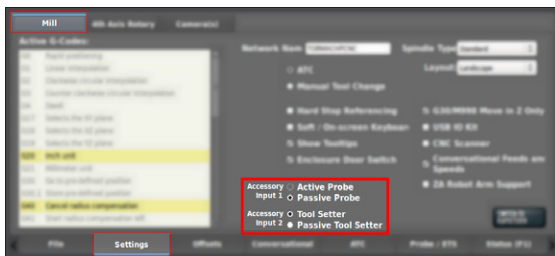


Figure 7-46: Settings tab.

7.2.14 Use the RapidTurn Interface

If you have a RapidTurn, you must first change the PathPilot interface.

To use the RapidTurn interface:

- From the **Settings** tab, select **Switch to RapidTurn**.

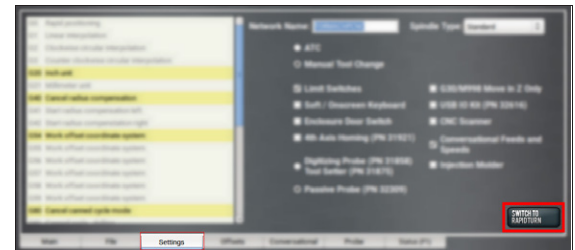


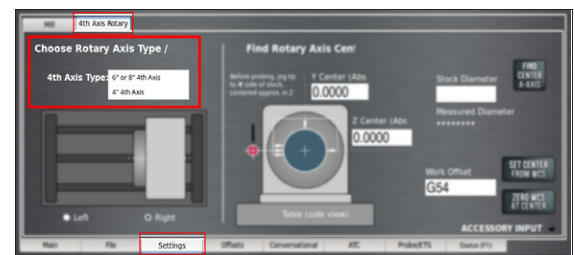
Figure 7-47: Switch to RapidTurn button on the Settings tab.

The PathPilot interface for the mill closes, and the PathPilot interface for the RapidTurn opens.

7.2.15 Specify the 4th Axis Rotary Type

To select the 4th axis that you're using:

- From the **Settings** tab, select the **4th Axis Rotary** tab.
- Then, from the **4th Axis Type** drop-down menu, select **4" 4th Axis**.



Note: Once you change the axis scale, you may see a message indicating a **Joint 3 following error**. If you do, select **Reset**, and the new axis will function as normal.

Enable the 4th Axis Homing Kit

If you have a 4th Axis Homing Kit (PN 31921), you must first enable it in the PathPilot interface.

To enable the 4th Axis Homing Kit:

- From the **Settings** tab, select the **4th Axis Rotary** tab.
- Then, select **4th Axis Homing (PN 31921)**.

7: PATHPILOT TOOLS AND FEATURES
7.2 Machine Settings and Accessories

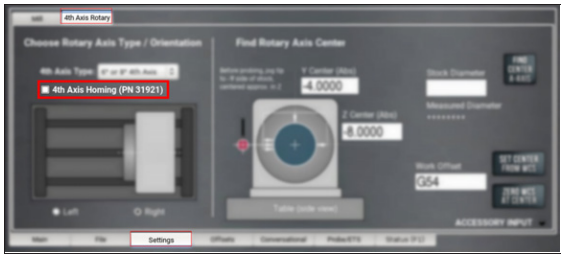


Figure 7-48: Settings tab.

7.2.16 Use a USB Camera

After plugging in the USB camera, navigate to the camera settings. From the PathPilot interface, in the Settings tab, open the Camera(s) tab. Identify the Camera Status read-only dialog box.



Figure 7-49: USB camera status.

As cameras are plugged in and unplugged, the Camera Status area is refreshed. To test compatibility of any USB camera, plug it in and watch the Camera Status area for the camera name and details.

Note: If a camera isn't shown after plugging it in or starting a video recording, it might require too much power from the USB ports on the controller. This is very likely when more than one camera is used. Try using a powered USB hub to add the camera(s).

When a USB camera is plugged in, it's analyzed for supported video and audio formats, frame sizes, and frame rates. If the camera supports it, PathPilot uses H.264 compression; otherwise, it uses Motion JPEG. If the USB camera has a microphone, PathPilot records audio as well as video. The preferred format is compressed AAC, but uncompressed PCM is used as a fallback.

About USB Cameras

Recording video and audio from USB cameras is supported in PathPilot v2.10.0 and later. You can use up to four cameras simultaneously to record from different vantage points.

Note: All cameras are started and stopped at the same time — if you don't want a camera to record, you must unplug it.

USB cameras are compatible with all machine types, but older controllers may lack the processing power and memory needed for camera support. Controllers require 4GB of memory for camera functionality. Use the ADMIN MEMORY MDI command to verify the memory size of a controller. You can purchase a Tormach USB Camera (PN 51240) with a metal case, mounting bracket, and 15-foot USB cable. Other USB cameras may work (see below), but do not include any technical support.

Manual Recording

To start or stop a manual recording, either:

- Use the controls in the Manual Recording area of the Camera(s) tab.

When a manual recording is stopped, a file save-as dialog appears prompting you for the file name base to use.

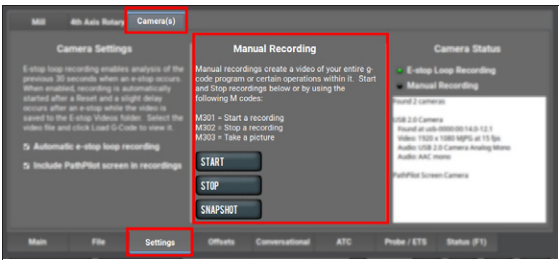


Figure 7-50: Manual recording controls.

- Select the **Video Camera Recording** button in the **Persistent Controls** section.

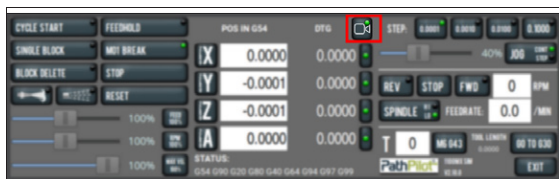


Figure 7-51: Video Camera Recording button.

Whenever PathPilot is recording from a USB camera and/or the virtual screen camera, the LED on this button is green. If PathPilot is recording and the button is pressed:

- If a program is running and not paused at an M00/M01, the recording is aborted.
- If a program is not running, but the machine is moving, the recording is aborted.
- Otherwise, if a manual recording is in progress, it is stopped and a file save as dialog will appear. If an automatic e-stop loop recording is in progress, it is aborted since no e-stop occurred.

To include a screen recording:

1. Toggle the **Include PathPilot screen in recordings** checkbox in the **Camera Settings** area of the **Camera(s)** tab to enable or disable screen recording.

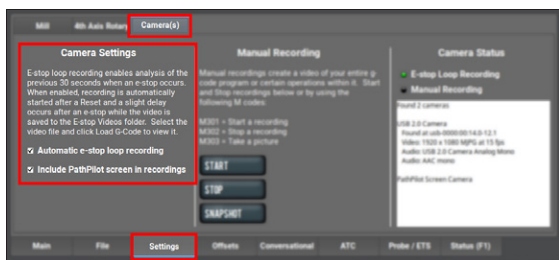


Figure 7-52: Camera settings.

To take a picture (using all of the USB cameras at once):

1. Select **Snapshot** in the **Manual Recording** area of the **Camera(s)** tab. The **Main** tab displays.
2. Review the camera images, which display on top of the **Tool Path** area. The camera images refresh every 0.5 seconds.
3. Align the cameras or adjust lighting to your preference, and then select the **Shutter** button.

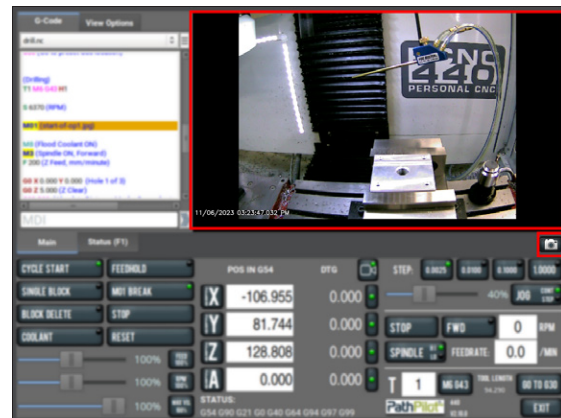


Figure 7-53: Example of taking a photo.

Automatic E-Stop Loop Recording ("Dashcam")

E-stop loop recording enables analysis of the previous 30 seconds after an E-stop. When enabled, recording is automatically started after reset.

To enable or disable the recording of emergency stops:

1. Toggle the **Automatic e-stop loop recording** checkbox in the **Camera Settings** area of the **Camera(s)** tab.



Note: This feature is enabled by default.

Automatic E-stop loop recording starts when the **Reset** button is selected. If you selected **Video Camera Recording** to abort a previous E-stop loop recording, select **Reset** to start it again.

To view E-stop videos:

1. A slight delay occurs after an E-stop while the video is saved to the **E-stop Videos** folder. Select the video file, and then select **Load G-Code** to view it.



Note: The E-Stop Videos folder is automatically monitored for internal drive space use. If the folder size grows beyond 5 GB, the oldest video files are automatically deleted until the folder size becomes less than 5 GB.

Review Video and Image Files

1. On the **File** tab, select the video or image file and select **Load G-Code**.

A video player application starts or the image preview is displayed.

Alternatively, you could transfer the video or image files to a Windows or macOS computer for review.

7: PATHPILOT TOOLS AND FEATURES

7.2 Machine Settings and Accessories

File Naming Convention

For manual and automatic E-stop recordings, the base file name for the recording has automatically chosen suffixes appended for each camera.

For example, if you stop a manual recording of two cameras, specify “Left Bracket Op1” as the name, and enabled screen recording, you'll see the following files:

File Name	Description of File
Left Bracket Op1_0.mp4	Camera 0 mp4 video file
Left Bracket Op1_0.log	Troubleshooting log for camera 0
Left Bracket Op1_1.mp4	Camera 1 mp4 video file
Left Bracket Op1_1.log	Troubleshooting log for camera 1
Left Bracket Op1_PP.mp4	PathPilot screen recording mp4 video file
Left Bracket Op1_PP.log	Troubleshooting log for screen recording

G-Code Commands

PathPilot supports three new M-codes to control cameras within G-code programs: M301, M302, and M303. Example use cases:

- Record only across each M01 stop where the operator needs to flip a workpiece or change a tool.
- Create short videos that focus on unique aspects of the program to reduce later video editing.
- Record USB IO integration operations with robots or other devices (pneumatic vises, etc.).
- Monitor progress on a workpiece by including M303 throughout the program.

File Naming Conventions

Recordings or pictures created by M301/M302/M303 have automatically generated file names, with the base file name taken from the running G-code file. Video files are saved alongside the G-code file. The suffix for each file uses a time stamp format. This makes it easy to distinguish multiple runs of the same G-code program.

For example, if engrave.nc is running and uses M301 and M302 to create one recording on a machine with one camera, and screen recording is enabled, you'll see the following files:

File Name	Description of File
engrave_2023-02-21_16_58_33_0.mp4	Camera 0 mp4 video file
engrave_2023-02-21_16_58_33_0.log	Troubleshooting log for camera 0
engrave_2023-02-21_16_58_33_PP.mp4	PathPilot screen recording mp4 video file
engrave_2023-02-21_16_58_33_PP.log	Troubleshooting log for screen recording
engrave_2023-02-21_17_43_22.jpg	Picture taken by a single M303 later in the program

Use M01 to Take Pictures

In addition to displaying information like pictures or messages during an M01 break, you can also use a USB camera (if installed) to take a picture.

To use M01 to take pictures:

- Add `M01 (op1_setup.jpg)` into your G-code program.
 - Run the G-code program.
 - When PathPilot executes the M01 it looks to see if the comment contains a file name.
 - If there isn't a file name: The comment is shown as instructional text across the tool path.
 - If there is a file name, but the file doesn't exist yet and the extension is .jpg, .png, or .jpeg: The USB cameras are initialized and shown in the tool path display.
 - Select the **Shutter** button to take the picture and create the op1_setup.jpg file.
- In future runs of the G-code program, **op1_setup.jpg** will display to the operator for instructional purposes on the workpiece.

For more information, see "Display Information and Capture Images During an M00 or M01 Break" (page 208).

7.3 SET UP G-CODE PROGRAMS

Before running a G-code program, you must first make sure that the machine is properly set up for the specific G-code program.

7.3.1 Use a Probe with PathPilot	143
7.3.2 Set Tool Length Offsets	145
7.3.3 Set Work Offsets	148
7.3.4 View Work Offsets	149
7.3.5 View Available G-Code Modes	149

7.3.1 Use a Probe with PathPilot

Use the Probe tab in the PathPilot interface to automate functions with a probe.

Set Up the Probe

Before using the functions on the Probe tab, you must first do the following:

1. Verify that tool number 99 (the probe tool) is in the spindle.
2. Disable the spindle to prevent any accidental spindle starts with the probe in the spindle.
3. Verify that the feed rate is appropriate for probing moves.

Note: All probing moves occur at a feed rate specified by the DRO fields on the Probe Setup tab.

4. Press the probe tip and make sure that, from the PathPilot interface, on the Probe tab, the Accessory Input light comes on.

This indicates that the probe polarity is correctly specified.

If the Accessory Input light does not come on, you must change the probe polarity setting. For information, see "Specify Probing and Tool Measuring Options" (page 139).

Use a Probe to Find a Feature's Location

To find the location of a workpiece or vise in the current work offset coordinates:

1. From the PathPilot interface, on the **Probe** tab, select the **X/Y/Z Probe** tab.
2. Position the probe near the workpiece or vise.
3. One at a time, select **Find X+**, **Find X-**, **Find Y+**, **Find Y-**,

or **Find Z-**.

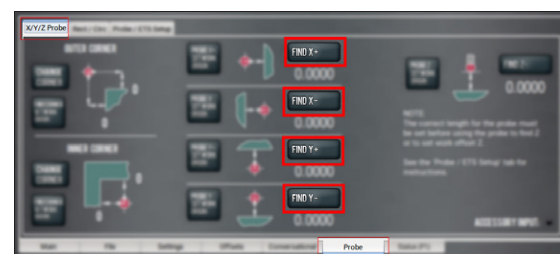


Figure 7-54: Probe tab.

The axis is probed, and the location of the probed surface is displayed.

Use a Probe to Set Work Offset Zeroes

You can set the work offsets of a workpiece or vise jaw using a probe.

Set the X and Y Work Offset Zero on the Corner of a Feature

1. From the PathPilot interface, on the **Probe** tab, select the **X/Y/Z Probe** tab.
2. Position the probe so that it is below the surface of the feature and 1 in. away from the vice jaw corner in the **X** and **Y** directions.
3. Select **Find Corner, Set Work Origin**.



Figure 7-55: Probe tab.

The axes are probed, and the location of the probed surface is set as the current work offset's X/Y origin.



Note: Select **Change Corner** to change the corner on which to probe.

Set the Work Offset Zeroes on a Feature

1. From the PathPilot interface, on the **Probe** tab, select the **X/Y/Z Probe** tab.
2. Position the probe near the workpiece or vise.

7: PATHPILOT TOOLS AND FEATURES

7.3 Set Up G-Code Programs

- One at a time, select **Probe X+**, **Set Work Origin**, **Probe X-**, **Set Work Origin**, **Probe Y+**, **Set Work Origin**, **Probe Y-**, **Set Work Origin**, or **Probe Z-**, **Set Work Origin**.

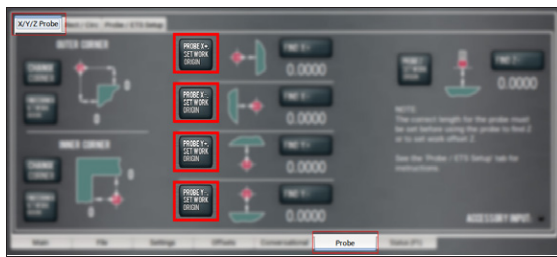


Figure 7-56: Probe tab.

The axis is probed, and the location of the probed surface is set as the current work offset's origin.

Use a Probe to Find the Center of a Feature

You can find the center of a pocket, slot, or boss on a part using a probe.

Find the Center of a Pocket

- From the PathPilot interface, on the **Probe** tab, select the **Rect/Circ** tab.
- Position the probe near the center of the pocket.
- Select **Find Center, Set Work Origin** as shown in the following image.



Figure 7-57: Probe tab.

Find the Center of a Slot

- From the PathPilot interface, on the **Probe** tab, select the **Rect/Circ** tab.
- Position the probe near the center of the slot.
- Depending on the slot, do one of the following:
 - To probe the slot in the **X** direction only, select **Find Center, Set Work Origin** as shown in the following image.

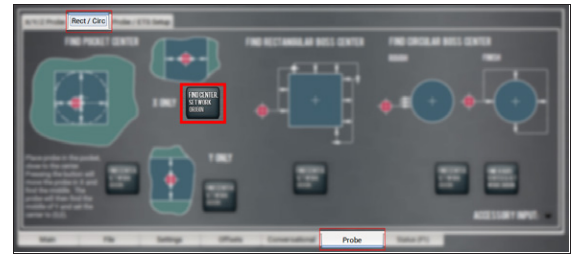


Figure 7-58: Probe tab.

- To probe the slot in the **Y** direction only, select **Find Center, Set Work Origin** as shown in the following image.

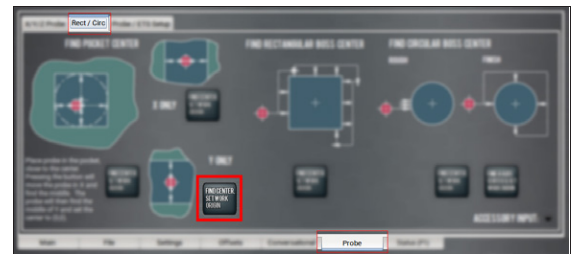


Figure 7-59: Probe tab.

Find the Center of a Rectangular Boss

- From the PathPilot interface, on the **Probe** tab, select the **Rect/Circ** tab.
- Position the probe below the top surface of the boss and on the left-hand side.
- Select **Find Center, Set Work Origin** as shown in the following image.

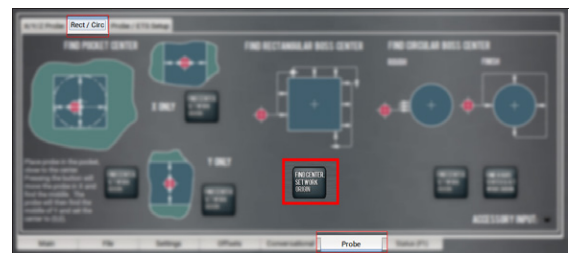


Figure 7-60: Probe tab.

The probe moves around the edge of the workpiece to find the center.

Find the Center of a Circular Boss

- From the PathPilot interface, on the **Probe** tab, select the **Rect/Circ** tab.
- Position the probe below the top surface of the boss and on the left-hand side.

3. Select **Find Center, Set Work Origin** as shown in the following image.

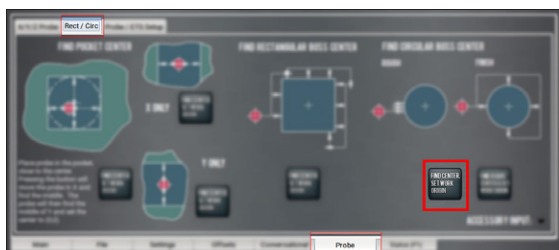


Figure 7-61: Probe tab.

The probe moves around the workpiece three times to determine the approximate center of the curve, and then makes four additional move to confirm the center of the circle.

Find the Center Rotation of an A-Axis

1. From the PathPilot interface, on the **Probe** tab, select the **Rect/Circ** tab.
2. Position the probe directly above the A-axis center of rotation.
3. Select **Find A Axis Center & Set Work Origin**.

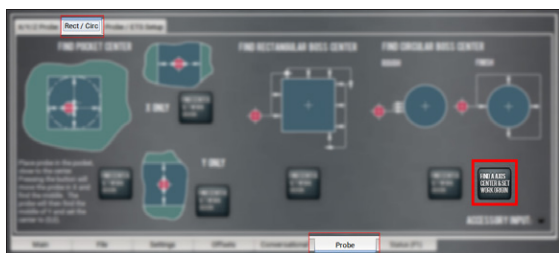


Figure 7-62: Probe tab.

The probe moves around the round workpiece mounted in the A-axis to find the center rotation of the A-axis.

7.3.2 Set Tool Length Offsets

Before running a G-code program, PathPilot must know the length of the tools that are required for the program. For more information on using tool length offsets, see "About Tool Offsets" (page 176).



Note: You can import a .csv file with tool length offset data. For information, see "Import and Export the Tool Table" (page 166).

To set tool length offsets:

1. Verify that the machine is powered on and out of reset.
2. Put a tool into a tool holder, and set it aside to measure.
For information, see "Set Up Tooling" (page 175).

3. From the PathPilot interface, on the **Offsets** tab, verify that the **Tool** tab is selected.
4. Find the **Tool Table** window.

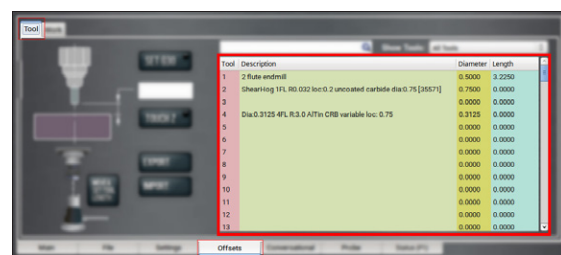


Figure 7-63: Tool Table window on the Offsets tab.

5. Depending on your workflow, you can measure your tools using any of the following methods:
 - **Use a Tool Height Setter** For information, see "Use a Tool Height Setter to Measure Tools" (page 178).
 - **Use an Electronic Tool Setter** For information, see "Use an Electronic Tool Setter (ETS) to Measure Tools" (page 178).
 - **Touch Off of a Known Reference Height** For information, see "Touch Off the Tool Length Offsets" (page 176).

About Tool Offsets

Tool offsets allow you to use various tools while still programming with respect to the workpiece. Tools can have different lengths (and, while using cutter radius compensation, different diameters).

The most common tool offset is the tool length offset: when you change tools, PathPilot must account for the difference in tool length. In CNC machines, the tool length offset is applied using a G43 command.

The tool length offset is the distance from the cutting edge of the tool to the shoulder of the tool holder.

Before you begin a G-code program, you must verify the lengths of the tools in the program, and make sure that the lengths agree with the tool length offsets set in PathPilot:

- Each time you change tools, you must apply a new tool length offset in PathPilot.

7: PATHPILOT TOOLS AND FEATURES
7.3 Set Up G-Code Programs

- Each time you replace a tool, you must remeasure its length, and apply a new tool length offset in PathPilot.

NOTICE! You must always verify that the physical length of a tool agrees with the tool length offset value set in PathPilot. If you don't, there's a risk that the tool length offset misrepresents the currently active tool in the spindle, which may result in a machine crash or damaged tooling, workpieces, or fixtures.

Touch Off the Tool Length Offsets

Touch off the tool length offsets by using a reference surface with a known height, which gives you a basis to measure any other tool lengths. Use any surface that is parallel (within 0.02 mm) to the machine table. For example:

- A 1-2-3 Block Set (PN 31950)
- Box parallel

There are two steps to touch off the tool offsets. Complete the following steps in the order listed:

Set a Known Reference Height 146
Measure Tools Using a Known Reference Height 146

Set a Known Reference Height

This procedure sets a new Z zero position for the currently selected work offset.

To set a known reference height:

- Identify a precision surface to use as a reference surface (like a 1-2-3 Block Set), and put it below the spindle on the machine table. Verify that there's a clear path from the spindle to the machine table.
- Verify that the drive dogs won't contact the reference surface before the end face of the spindle.
- Set a new, unused work offset (like G55). From the PathPilot interface, on the Main tab, in the MDI Line DRO field, type a work offset. Then select the Enter key. For information, see "Set Work Offsets" (page 180).
- If there's already a tool in the spindle, remove it.
- From the PathPilot interface, in the Tool DRO field, type 0. Then select the Enter key.
- Slowly jog the Z-axis down (-Z) until it's 0.04 in. (1 mm) from the reference surface.

- Measure the thickness of a piece of paper, and put the paper on the reference surface. Note the thickness of the paper for later.
- While moving the paper back-and-forth across the reference surface, slowly step the Z-axis down (-Z) until you feel a light pull on the piece of paper. This indicates that the paper is contacting the end face of the spindle.

Note: It's easier to use step jogging for this task. For information on step jogging, see "About Step Jogging" (page 171).

- From the PathPilot interface, in the Z-axis work offset DRO field, type the thickness of the piece of paper. Then select the Enter key.



Figure 7-64: Z-axis work offset DRO field.

The reference surface is now set as the Z zero position in the current coordinate system.

- To set the tool length offset, go to Measure Tools Using a Known Reference Height.

Measure Tools Using a Known Reference Height

This procedure sets the tool length offset using a known reference height. If you have not yet done so, you must first set the Z zero position; go to Set a Known Reference Height.

To measure tools using a known reference height:

- Verify that the reference surface is still on the machine table with the piece of paper.
- From the PathPilot interface, on the Offsets tab, find an unused tool number in the Tool Table window. Then, type a description for the tool you're measuring.
- Put the tool holder into the spindle.
- From the PathPilot interface, in the Tool DRO field, type the number of the tool. Then select the Enter key.



Figure 7-65: Tool DRO field.

5. Slowly jog the Z-axis down (-Z) until it is 0.04 in. (1 mm) from the reference surface.
6. Continue to slowly jog the Z-axis while slowly moving the piece of paper back-and-forth on the reference surface.
7. Stop jogging the Z-axis when you feel a light pull on the piece of paper, which indicates that it is in contact with the tool.
8. From the PathPilot interface, on the **Offsets** tab, in the **Tool Table**, select the tool for which you previously wrote a description.
9. In the **Touch Z** DRO field, type the thickness of the piece of paper. Then select the **Enter** key.

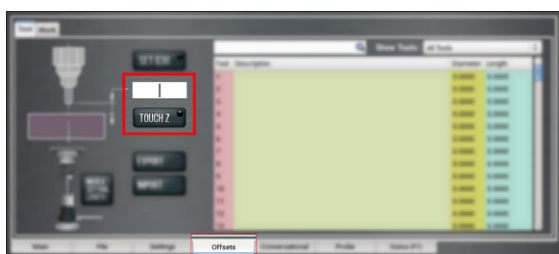


Figure 7-66: Touch Z DRO field and button.

10. Select **Touch Z**.
The length of the tool is stored in the **Tool Table** window.
11. From the **Tool Table** window, in the **Length** column, verify that the length of the tool is correct.
12. In the **Diameter** column, type the diameter of the tool. Then select the **Enter** key.
13. Jog the Z-axis up (+Z).
You've completed the procedure to measure a tool offset. Repeat this procedure for any remaining tooling you have. Once you're done adding tool length offsets, switch back to your work coordinate system.

Use an Electronic Tool Setter (ETS) to Measure Tools

An ETS is a device used to measure the length of a cutting tool. To use an ETS to measure tools:

1. Put the ETS on the known reference surface below the spindle.
2. From the PathPilot interface, on the **Offsets** tab, in the **Tool Table** window, in the **Description** column, type a description for the tool.
3. In the **Diameter** column, type the diameter of the tool. Then select the **Enter** key.

4. Put a tool holder into the spindle.
5. From the PathPilot interface, type the tool number in the **Tool DRO** field. Then select the **Enter** key.

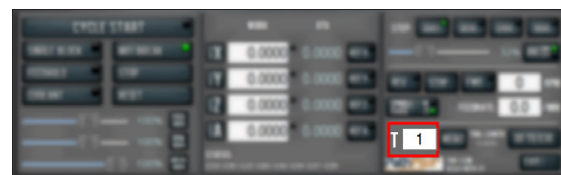


Figure 7-67: Tool DRO field.

6. Jog the Z-axis down (-Z) until it is above the ETS.
7. From the **Offsets** tab, on the **Tool** tab, select **Move and Set Tool Length**.

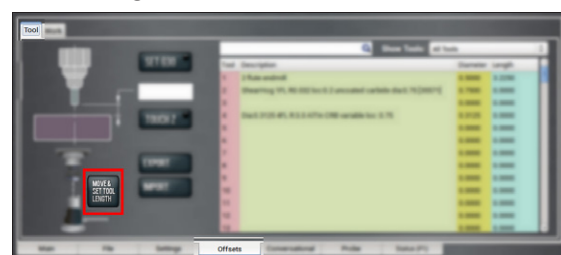


Figure 7-68: Tool tab on the Offsets tab.

Note: Regardless of the initial feed rate, the final touch off feed rate while using an ETS is 2-1/2 in. per minute (IPM).

8. From the **Tool Table** window, in the **Length** column, verify that the length of the tool is correct.

Use a Tool Height Setter to Measure Tools

This procedure sets the tool length offset using a known reference height and a Tool Height Setter (PN 39682).

Complete the following steps in the order listed:

- Set a Known Reference Height** 147
- Verify the Calibration of the Tool Height Setter**148

Set a Known Reference Height

This procedure sets a new Z zero position for the currently selected work offset.

To set a known reference height:

1. Identify a precision surface to use as a reference surface (like a 1-2-3 Block Set), and put it below the spindle on the machine table. Verify that there's a clear path from the spindle to the machine table.

7: PATHPILOT TOOLS AND FEATURES

7.3 Set Up G-Code Programs

2. Set a new, unused work offset (like G55). From the PathPilot interface, on the **Main** tab, in the **MDI Line** DRO field, type a work offset. Then select the **Enter** key. For information, see "Set Work Offsets" (page 180).
3. If there's already a tool in the spindle, remove it.
4. From the PathPilot interface, in the **Tool** DRO field, type 0. Then select the **Enter** key.
5. Slowly jog the Z-axis down (-Z) until it's 0.04 in. (1 mm) from the reference surface.
6. Measure the thickness of a piece of paper, and put the paper on the reference surface. Note the thickness of the paper for later.
7. While moving the paper back-and-forth across the reference surface, slowly step the Z-axis down (-Z) until you feel a light pull on the piece of paper. This indicates that the paper is contacting the end face of the spindle.



Note: It's easier to use step jogging for this task. For information on step jogging, see "About Step Jogging" (page 171).

8. From the PathPilot interface, in the **Z-axis** work offset DRO field, type the thickness of the piece of paper. Then select the **Enter** key.

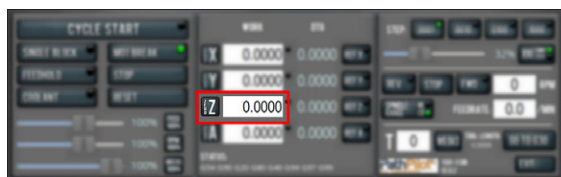


Figure 7-69: Z-axis work offset DRO field.

The reference surface is now set as the Z zero position in the current coordinate system.

Verify the Calibration of the Tool Height Setter

The higher side of the Tool Height Setter is precision ground. You can use it as a reference surface to calibrate the tool.

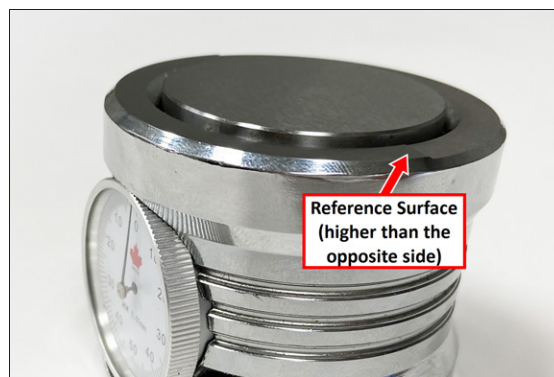


Figure 7-70: Tool Height Setter.

1. Use the provided dowel pin to compress the setting face of the Tool Height Setter to the level of the ground reference surface.
2. Adjust the indicator dial's bezel to read zero. Make note of how many times the indicator rotates around the dial.
3. Measure the height of the ground reference surface from the bottom surface of the Tool Height Setter with a calipers. Note the measured height for later.
4. Carefully, without moving the bezel, put the Tool Height Setter on the reference surface that's on the machine table.
5. Measure the tools using a known reference height.

7.3.3 Set Work Offsets

To set the current axis location to zero in the active work coordinate system:

- Select **Zero [Axis]**.

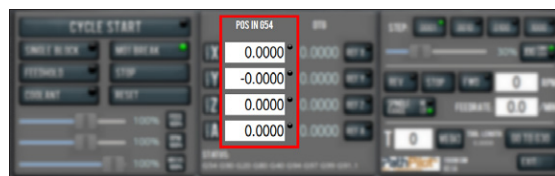


Figure 7-71: Work Offset DRO fields.

To change work offsets:

1. On the **Main** tab, in the **MDI Line** DRO field, type the new work offset to activate (for example, G55). Then select the **Enter** key.

- The new work offset displays in the following locations in the PathPilot interface:
 - The **Status** read-only DRO field.
 - Above the **Work Offset** DRO fields.



Figure 7-72: Work offset indicated in the PathPilot interface.

Note: The values in the **Work Offset** DRO fields update to indicate the new location of each axis in the new work offset.

For more information on using work offsets, see "About Work Offsets" (page 180).

About Work Offsets

Work offsets allow you to think in terms of X, Y, and Z coordinates with respect to the part, rather than thinking of them with respect to the machine position. This means that you can jog the machine to an arbitrary location (like the end of a workpiece) and call that location zero. You can save up to 500 work offsets in PathPilot. The naming structure varies based on the offset number, as detailed in the following table.

Work Offset Naming		
Offsets 1-9 (Use either name)		
Offset	Extended Name	Name
1	G54.1 P1	G54
2	G54.1 P2	G55
3	G54.1 P3	G56
4	G54.1 P4	G57
5	G54.1 P5	G58
6	G54.1 P6	G59
7	G54.1 P7	G59.1
8	G54.1 P8	G59.2
9	G54.1 P9	G59.3

Work Offset Naming		
Offsets 10-500 (Use extended name)		
Offset	Extended Name	Name
10	G54.1 P10	Not used
11	G54.1 P11	Not used
...		
499	G54.1 P499	Not used
500	G54.1 P500	Not used

7.3.4 View Work Offsets

To view the current work offset:

- From the **Offsets** tab, on the **Work** tab, identify the **Work Offsets Table** window.

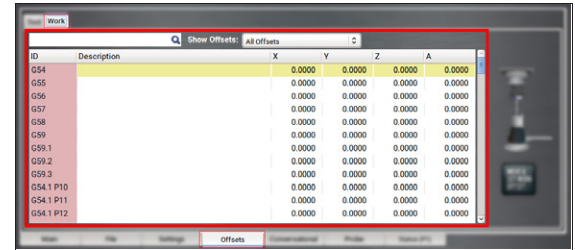


Figure 7-73: Work Offsets Table window.

The active work offset is highlighted.

To change the current work offset, go to "Set Work Offsets" (page 180).

7.3.5 View Available G-Code Modes

The G-Code Description window shows a list of all available G-code modes.

To view available G-code modes:

- From the **Settings** tab, find the **G-Code Description** window.

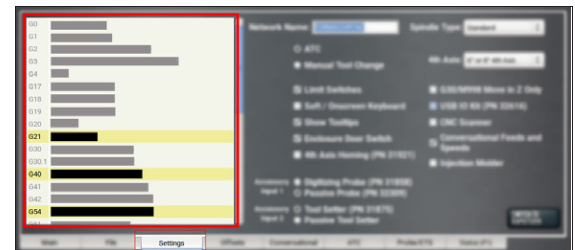


Figure 7-74: G-code Description window on the Settings tab.

7: PATHPILOT TOOLS AND FEATURES

7.4 Run G-Code Programs

7.4 RUN G-CODE PROGRAMS

While running a G-code program, use the following controls:

7.4.1 Bring the Machine Out of Reset	150
7.4.2 View the Active Axis to Jog	150
7.4.3 Jog the Machine	150
7.4.4 View the Current Machine Position	151
7.4.5 Reference the Machine	152
7.4.6 Start a Program	152
7.4.7 Stop Machine Motion	153
7.4.8 Operate the Coolant Pump	153
7.4.9 View the Active G-Code Modes	153
7.4.10 View the Distance to Go	153

7.4.1 Bring the Machine Out of Reset

- Select **Reset**.



Figure 7-75: Reset button.

For more information on reset mode, see "About Reset Mode" (page 169).

About Reset Mode

When the machine is first powered on, or after an emergency stop, the Reset button flashes. When you select the flashing Reset button, PathPilot verifies communication to the machine and does the following activities:

- Brings the machine out of an emergency stop condition
- Clears alarms
- Clears the tool path backplot
- Resets all modal G-codes to their normal state
- Rewinds the currently loaded G-code program
- Stops machine motion, but is **not** a replacement for the Emergency Stop button

You can select the Reset button any time while the machine is on.

7.4.2 View the Active Axis to Jog

To find which axis is active while jogging your machine:

- Identify the light next to the **Work Offset** DRO fields.



Figure 7-76: Work Offset DRO fields.

For information, see "Jog the Machine" (page 171).

7.4.3 Jog the Machine

To switch between jogging modes:

- From the **Manual Control** area, in the **Jog** group, select **Jog**.

PathPilot toggles between continuous velocity mode and step mode.



Figure 7-77: Jog button.

When the **Cont** green light is on, continuous velocity mode is selected.

When the **Step** green light is on, step mode is selected.

To use continuous velocity mode:

- Set the velocity: drag the **Jog Speed** slider.



Figure 7-78: Jog Speed slider.

For more information on continuous velocity mode, see "About Continuous Velocity Jogging" (page 171).

To use step mode, select the step size. Do one of the following, depending on your accessories:

- In the **Manual Control Area**, in the **Jog** group, select the step size.

The **Step** button's light comes on, indicating which step size is active.



Figure 7-79: Step buttons (in G20 mode).

- On the (optional) Jog Shuttle, press the Step button to toggle the currently selected step size.
In the PathPilot interface, the **Step** button's light comes on, indicating which step size is active.

For more information on step mode, see "About Step Jogging" (page 171).

Jog in Continuous Velocity Mode

In continuous mode, the machine jogs at a continuous velocity.
To select continuous velocity mode:

- In the **Manual Control** area, select **Jog**.



Figure 7-80: Continuous velocity jogging controls.

When the **Cont** green light is on, continuous velocity mode is selected.

When the **Step** green light is on, step mode is selected.

To set the velocity:

- Drag the **Jog Speed** slider.

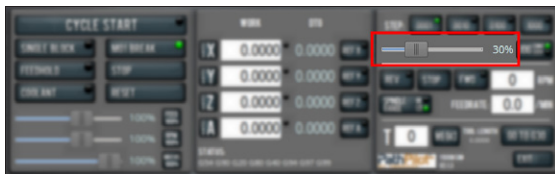


Figure 7-81: Jog Speed slider.

About Continuous Velocity Jogging

While jogging in continuous velocity mode, the machine moves at a constant speed for as long as:

- A keyboard key is pressed
- The Jog Shuttle outer ring is twisted away from the neutral position
- The Operator Console's pendant wheel is turned in the desired direction

This is useful when you're doing things like:

- Roughly positioning the machine (for example, to move the spindle head away from the workpiece).
- Moving the machine a certain distance at a constant speed (for example, to align a vise).

Jog in Step Mode

In step mode, the machine jogs in steps, which range based on the programming mode you're using:

- Imperial (G20) Mode** 0.0001 in. to 0.1000 in.
- Metric (G21) Mode** 0.01 mm to 10 mm

To select the step size:

- In the **Manual Control Area**, select the step size.
The **Step** button's light comes on, indicating which step size is active.

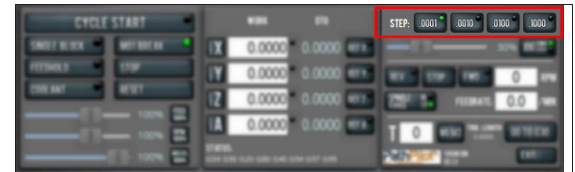


Figure 7-82: Step buttons (in G20 mode).

About Step Jogging

While jogging in step mode, the machine moves one step at a time. The jog step sizes range depending on the programming mode you are using:

- Imperial (G20) Mode** 0.0001 in. to 0.1000 in.
- Metric (G21) Mode** 0.01 mm to 10 mm

Step jogging mode is useful to finely move the machine, like when you're indicating a workpiece or manually setting tool lengths.

The jog keys on the keyboard only move the machine in steps when step mode is indicated in PathPilot. The inner wheel on the jog shuttle always moves the machine in steps, regardless of which mode is indicated in PathPilot. The Operator Console's pendant moves the machine in the step size that's selected with the three-position switch.

7.4.4 View the Current Machine Position

- Identify the **Work Offset** DRO fields.

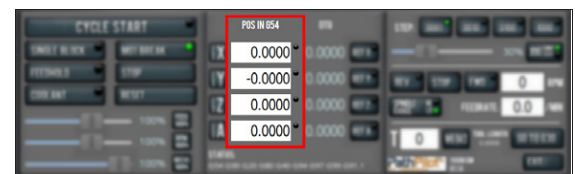


Figure 7-83: Work Offset DRO fields.

The position is expressed by the currently active work offset coordinate system (like G54 or G55).

When the machine isn't moving, you can edit the DRO fields.
For more information on setting work offsets, go to "Set Work Offsets" (page 180).

7: PATHPILOT TOOLS AND FEATURES

7.4 Run G-Code Programs

7.4.5 Reference the Machine



Note: The machine automatically references when it's powered on.

1. Verify that the machine can freely move to its reference position (at the ends of travel).
2. To verify that the tooling is clear of any possible obstructions, reference the Z-axis before referencing the other axes: from the PathPilot interface, select **Ref Z**.



Figure 7-84: Reference buttons.

3. Once the spindle is clear of any possible obstructions, continue referencing all axes.



Note: You can select the buttons one after another. Once the machine references one axis, it'll move on to the next.

After each axis is referenced, its button light comes on.

For more information on referencing the machine, see About Referencing.

About Referencing

The axes are referenced during assembly and, aside from the A-axis, do not need re-referencing after powering on or once the Emergency Stop button is released. You must reference the X-, Y-, or Z-axis or the ATC at the following times:

- After replacement of a linear motion component such as linear rails, ballscrew, or servo motor
- Disconnection of an encoder battery and powering off of the machine
- Disconnection of the encoder cable from the servo motor

When referencing the X-, Y-, and Z-axis, the machine moves to the end of travel, presses against the bumper on the ballscrew until torque increases, and then backs off to the index pulse of the encoder.

You must reference the A-axis only if the rotary table is removed from the machine.

When referencing the A-axis, the machine lines up the index marks on the body and face plate, then backs off to the index pulse of the encoder.

To reference the ATC, select the **Align Tool Tray** button on the **ATC** tab. When referencing, an ATC pocket is aligned to the flange of a tool holder in the spindle until both parts of the ATC fork open evenly when engaging the flange of the tool holder.



Figure 7-85: Align Tool Tray button on the ATC tab.

7.4.6 Start a Program



From the PathPilot interface, in the **Main** tab, select **Cycle Start**.

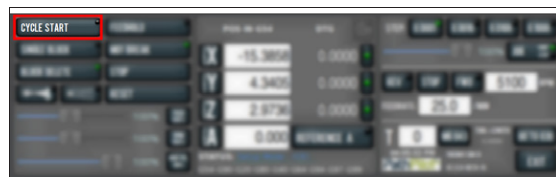


Figure 7-86: Cycle Start button.

For more information on starting a program, see "About Cycle Start" (below).

If you can't start a program, go to "Cycle Start Reference" (below).

About Cycle Start

While a program is running, the Cycle Start button's light is on. The Cycle Start button's light flashes if motion is paused during the program. The following modes may pause motion during a program:

- Single block
- Feed hold
- M01 break

If machine motion pauses a single block, feed hold, or M01 break, the Cycle Start button flashes until it's selected again.

Cycle Start Reference

The Cycle Start button doesn't operate if you select it:

- While you're not in the Main tab. For information, see "Main Tab" (page 107).

- Before you've loaded a G-code program. For information, see "Load G-Code" (page 174).
- Before referencing the machine. For information, see "Reference the Machine" (page 170).

7.4.7 Stop Machine Motion

- From the **Program Control** area, select **Stop**.

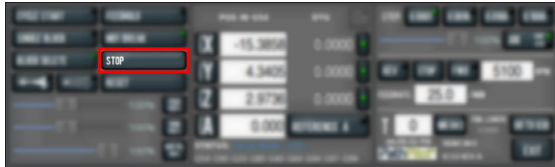


Figure 7-87: Stop button.

7.4.8 Operate the Coolant Pump

To turn coolant on or off:

- Select **Coolant**.

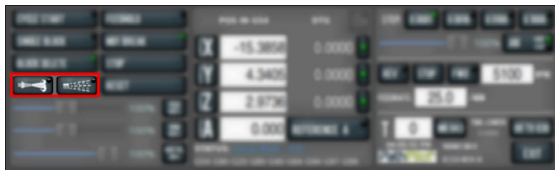


Figure 7-88: Coolant button.

For more information on turning on and off coolant, see "About Coolant" (page 181).

About Coolant

In the PathPilot interface, the Coolant button controls the machine's coolant pump power outlet. The Coolant button's light shows the current state of the outlet: the light is on when the outlet has power; the light is off when the outlet does not have power.



Note: The Coolant button is equivalent to using an M08 (coolant on) or M09 (coolant off) command in the G-code program.

Use the Coolant button before or after a program is running, while a program is running, or while you are using manual data input (MDI) commands.

7.4.9 View the Active G-Code Modes

To find the currently active G-code modes and the currently active tool at a glance:

- Identify the **Status** read-only DRO field.



Figure 7-89: Status read-only DRO field.

For more information on G-code modes, go to "View Available G-Code Modes" (page 149).

7.4.10 View the Distance to Go

To view the distance to go:

- Identify the **DTG** read-only DRO fields.

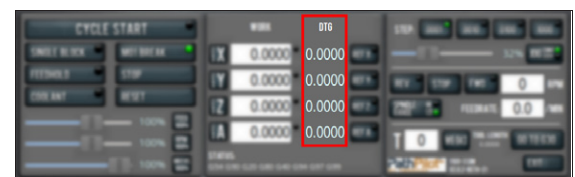


Figure 7-90: DTG read-only DRO fields.

The value is the remaining distance in any programmed move.

For more information on using the **DTG** read-only DRO fields, see "About Distance to Go" (below).

About Distance to Go

While a program is running, the DTG read-only DRO fields show the remaining distance in each move.

After using the feed hold function or the maxvel override function, look at the distance to go. This read-only DRO field is useful to prove out a part program.

7: PATHPILOT TOOLS AND FEATURES

7.5 Control G-Code Programs

7.5 CONTROL G-CODE PROGRAMS

If necessary, use the following controls to add to your G-code program:

7.5.1 Use the Feed Hold Function	154
7.5.2 Use the Feed Rate Override Function	154
7.5.3 Use M01 Break Mode	155
7.5.4 Use the Maxvel Override Function	155
7.5.5 Use Single Block Mode	156
7.5.6 Use the Spindle Override Function	156
7.5.7 Change the Feed Rate	157
7.5.8 Change the Spindle Speed	157
7.5.9 Change the Tool Number	157
7.5.10 Use a G30 Position	158
7.5.11 View the Tool Length	158
7.5.12 Manually Enter Commands	158
7.5.13 Copy Recently Entered Commands	159
7.5.14 Use Feeds and Speeds Suggestions	160
7.5.15 Use Cycle Counters (M30 and M99)	163

7.5.1 Use the Feed Hold Function

- Select **Feed Hold**.

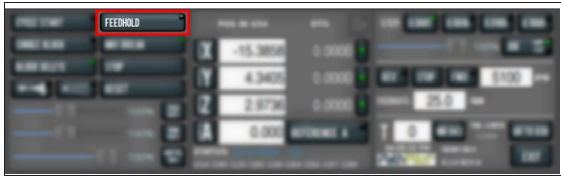


Figure 7-91: Feed Hold button.

Tip! Use the **Spacebar** key to quickly activate the feed hold function.

For more information on using the feed hold function, see "About Feed Hold" (below).

About Feed Hold

When the feed hold function is active, the Feed Hold button's light is on.

The feed hold function pauses machine motion — aside from the spindle — and the Cycle Start button flashes. For information, see "About Cycle Start" (page 152).

Note: If the machine isn't moving, the feed hold function doesn't have an effect.

You can use the feed hold function either while a program is running or while you are using manual data input (MDI) commands. If the program is running a spindle-synchronized move, the feed hold function is delayed until the move is complete.

7.5.2 Use the Feed Rate Override Function

To use the feed rate override function:

- Using the **Feed Rate Override** slider, change the programmed feed rate by a specific percentage.



Figure 7-92: Feed Rate Override slider.

Note: Percentages range from 1-200%.

To remove the feed rate override function:

- Select **Feed 100%**.
The feed rate returns to 100% of its programmed value (it's no longer overridden).

For more information on the feed rate override function, see "About Feed Rate Override" (below).

About Feed Rate Override

You can use the feed rate override function while you're doing any of the following activities:

- Using manual data input (MDI) commands
- Jogging
- Running a program with G01, G02, or G03 commands

The feed rate override function does not affect G00 (rapid) commands. It's ignored if:

- The program is running a spindle-synchronized move
- An M48 (disable feed and speed overrides) command is used

To indicate lack of motion or unusual levels, the slider turns yellow when it's either at 0% or above 100%.

The Feed Rate Override slider and Feed 100% button work similarly to the spindle override controls. They affect the commanded feed rate by a percentage from 1-200%. The feed rate override works for MDI, jogging, and G-code program G01/G02/G03 moves. The override has no effect on G00 (rapid) moves.

7.5.3 Use M01 Break Mode

- Select **M01 Break**.

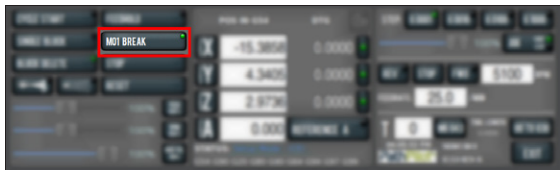


Figure 7-93: M01 Break button.

For more information on using M01 break mode, see "About M01 Break" (below).

About M01 Break

When the M01 break mode is active, the M01 Break button's light is on. When the M01 break mode is inactive, the M01 Break button's light is off.

M01 break mode enables any M01 (optional stop) commands that are programmed in the G-code file. You can turn M01 break mode on or off either before starting a program or while a program is running.

- **When M01 Break is Active** Machine motion stops after PathPilot reaches an M01 command, and the Cycle Start button flashes. For information, see "About Cycle Start" (page 152).
- **When M01 Break is Inactive** PathPilot ignores all programmed M01 commands.

Display Information and Capture Images During an M00 or M01 Break

Display Information with Images

If the comment occurs on a line with **M00** or **M01**, and contains a file name with a .jpg or .png extension, PathPilot displays the image in the Tool Path display when the program reaches the M00 or M01 break.

To display an image during an M00 or M01 break:

1. Move an image file with a .jpg or .png extension to the PathPilot controller in one of the following locations:
 - In the same folder as the G-code program
 - In an images folder within the G-code program's folder
 - In an images folder within the home directory
2. Program an M00 or M01 break, and, using parentheses, type the full file name of the image (including its extension).



EXAMPLE

M01 (Op1_Setup.jpg) displays the image file on the Tool Path display.

3. The image file displays on the Tool Path display.

Display Information with Text

To display a message on the Tool Path display:

1. Program an M00 or M01 break, and, using parentheses, type a message that you'd like to display on the screen.



EXAMPLE

M01 (Check coolant nozzles are pointed correctly) displays *Check coolant nozzles are pointed correctly* across the bottom of the Tool Path display.

2. The message displays on the Tool Path display.

Capture Images with a USB Camera

In addition to displaying information like pictures or messages during an M01 break, you can also use a USB camera (if installed) to take a picture.

To use M01 to take pictures:

1. Add **M01 (op1_setup.jpg)** into your G-code program.
2. Run the G-code program.
3. When PathPilot executes the M01 it looks to see if the comment contains a file name.
 - If there isn't a file name: The comment is shown as instructional text across the tool path.
 - If there is a file name, but the file doesn't exist yet and the extension is .jpg, .png, or .jpeg: The USB cameras are initialized and shown in the tool path display.
4. Select the **Shutter** button to take the picture and create the op1_setup.jpg file.
In future runs of the G-code program, **op1_setup.jpg** will display to the operator for instructional purposes on the workpiece.

For more information, see "Use a USB Camera" (page 140).

7.5.4 Use the Maxvel Override Function

To use the maxvel override function:

7: PATHPILOT TOOLS AND FEATURES

7.5 Control G-Code Programs

- Using the **Maxvel Override** slider, change the maximum velocity by a specified percentage.



Figure 7-94: Maxvel Override slider.

To remove the maxvel override function:

- Select **Maxvel 100%**.

For more information on using the maxvel override function, see "About Maxvel Override" (below).

About Maxvel Override

The maxvel override function affects G00 and G01 commands, and it's useful for:

- **Running a Program for the First Time** Drag the Maxvel Override slider to 0% to verify that all DRO fields look appropriate.
- **Safety** If you're running a spindle-synchronized move, a maxvel override isn't ignored. Verify that the maxvel override value allows the machine to use the programmed feed rate during spindle-synchronized moves. If it can't, the spindle-synchronized move won't produce the results you want.

To indicate lack of motion or unusual levels, the slider turns yellow when it's either at 0% or above 100%.

7.5.5 Use Single Block Mode

- Select **Single Block**.

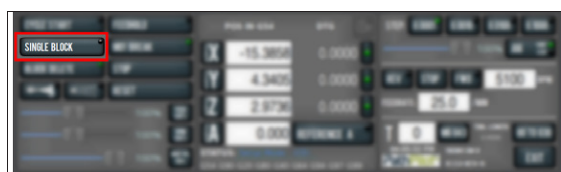


Figure 7-95: Single Block button.

For more information on using single block mode, see "About Single Block" (below).

About Single Block

While single block mode is active, the Single Block button's light is on.

Single block mode runs one line of G-code at a time. After each line, motion is paused, and the Cycle Start button flashes.

For information, see "About Cycle Start" (page 152).

You can turn single block mode on or off either before starting a program or while a program is running. For information, see "Use Single Block Mode" (above).



Note: Single block mode ignores non-motion lines, like comment lines or blank lines.

7.5.6 Use the Spindle Override Function

To use the spindle override function:

- Using the **Spindle Override** slider, change the programmed spindle speed by a specified percentage.

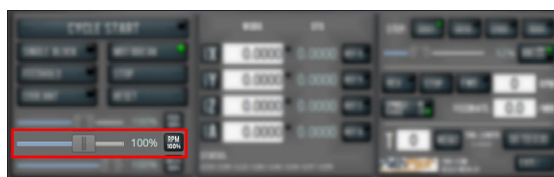


Figure 7-96: Spindle Override slider.



Note: Percentages range from 1-200%.

To remove the spindle override function:

- Select **RPM 100%**.
The spindle speed returns to 100% of its programmed value (it's no longer overridden).

For more information on using the spindle override function, see "About Spindle Override" (below).

About Spindle Override

The spindle override function won't command the spindle to move past the maximum allowable speed. If the spindle isn't moving, the spindle override function is delayed until the next time spindle starts. The override doesn't drive the spindle past its maximum speed. It does affect the speed of a spindle command limited by a D word.

You can use the spindle override function while you're doing any of the following activities:

- Running a program
- Using manual data input (MDI) commands

The spindle override function is ignored in the following situations:

- If the program is running a spindle-synchronized move
- If an M48 (disable feed and speed overrides) command is used

To indicate lack of motion or unusual levels, the slider turns yellow when it's either at 0% or above 100%.

7.5.7 Change the Feed Rate

- In the **Feed Rate** DRO field, type in a feed rate. Then select the **Enter** key.

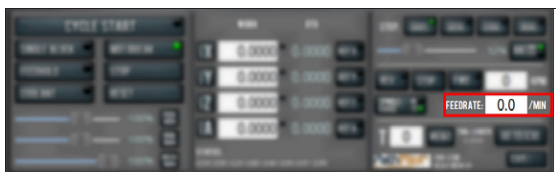


Figure 7-97: Feed Rate DRO field.

For information, see "About Feed Rates" (below).

About Feed Rates

A feed rate is the velocity at which the workpiece can be fed against the tool in the machine's spindle.

Motion	Feed Rate
Coordinated linear motion of one or more axis (X-axis, Y-axis, or Z-axis)	Inches per minute (G20) or millimeters per minute (G21)
Rotational axis motion of one axis (A-axis)	Degrees per minute
Coordinated linear motion of one or more axis (X-axis, Y-axis, or Z-axis) with simultaneous rotational axis motion (A-axis)	Usually programmed in inverse time feed rate mode (G93)

7.5.8 Change the Spindle Speed

- In the **Spindle RPM** DRO field, type in a spindle speed. Then select the **Enter** key.

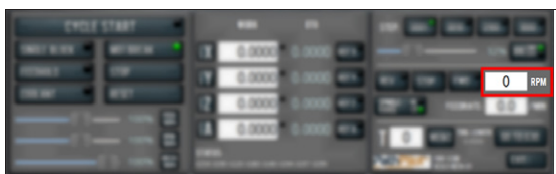


Figure 7-98: Spindle RPM DRO field.



Note: Verify that the spindle speed is within the specified range for the spindle belt's position. For information, see Change the Spindle Speed Range.

For information, see "About Spindle Controls" (below).

About Spindle Controls

A spindle speed is the rate at which the spindle rotates. Use the FWD, REV, and Stop buttons to manually control the spindle.

Button	G-Code	Use to...
FWD	M03	Start the spindle clockwise at the RPM specified in the Spindle RPM DRO field.
REV	M04	Start the spindle counterclockwise at the RPM specified in the Spindle RPM DRO field.
Stop	M05	Stop the spindle.

The FWD and REV buttons and the Spindle RPM DRO field don't operate if selected when:

- A G-code program is running.
 - Using manual data input (MDI) commands.
 - You type a value outside of the specified range for the spindle belt's position into the Spindle RPM DRO field.
- For information, see Changing the Spindle Speed Range.

7.5.9 Change the Tool Number

The Tool DRO field shows the tool number currently active.

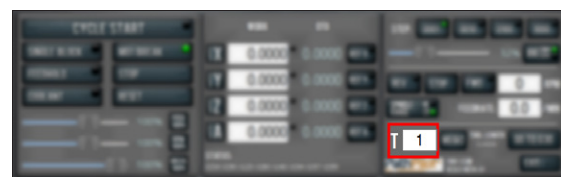


Figure 7-99: Tool DRO field.

To change the tool number (and apply its tool length offset):

1. In the **Tool** DRO field, type a number (the valid range is from 0-1000). Then select the **Enter** key.



Note: You can also select **M6 G43**. For information, see "About M6 G43" (below).

About M6 G43

The M6 G43 button is a shortcut used to do the following:

- Change the number of the currently-loaded tool in the spindle to the number typed in the Tool DRO field. This is the equivalent of an M06 command.

7: PATHPILOT TOOLS AND FEATURES
7.5 Control G-Code Programs

- Apply the tool length offset for that tool typed in the Tool DRO field. For more information on tool length offsets, see "Set Tool Length Offsets" (page 176). This is the equivalent of a G43 command.

7.5.10 Use a G30 Position

The Go to G30 button moves the machine to a predefined G30 position. For information, see "About G30" (below). To set a G30 position:

1. Jog the machine to the desired G30 position.
2. From the Offsets tab, select Set G30.

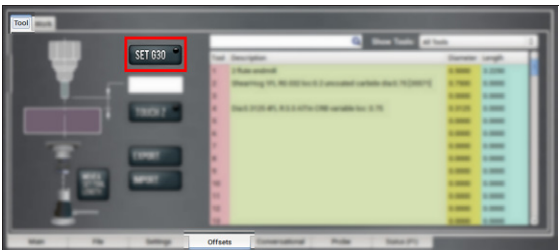


Figure 7-100: Set G30 button.

To go to a set G30 position:

- Use a G30 command in a G-code program.
- Select Go To G30.



Figure 7-101: Go to G30 button.



Note: The G30 position defaults to only moving the Z-axis.

About G30

A G30 command in a G-code program moves the machine to a preset position. For more information on setting a G30 position, see "Use a G30 Position" (above). Use a G30 move to start a coordinated movement of the axes. You can limit the movement to only the Z-axis. For information, see "Limit G30 Moves" (page 137).



Tip! It's useful to program a G30 move right before a tool change so that the machine can jog to a safe tool change position.

7.5.11 View the Tool Length

- Identify the Tool Length read-only DRO field.



Figure 7-102: Tool Length DRO field.

If the tool offset matches the number of the tool in the Tool DRO field, the text is light blue on a gray background. If the tool offset doesn't match the number of the tool in the Tool DRO field, the text is orange on a red background.

7.5.12 Manually Enter Commands

You can send G-code commands directly to the machine by using the MDI Line DRO field. For information, see "About the MDI Line DRO Field" (below).

To manually enter commands:

1. Select the MDI Line DRO field.

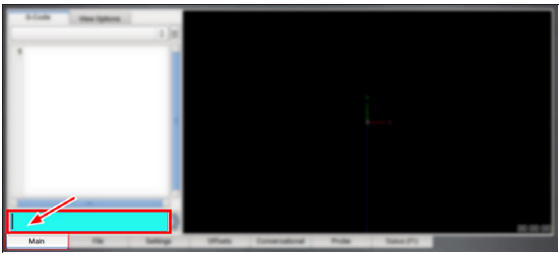


Figure 7-103: MDI Line DRO field.

The DRO field highlights.

2. Type the command.



Note: You can use the Backspace, Delete, Left Arrow, and Right Arrow keys to correct typing errors.

3. You must press the Enter key to execute the command. To abandon the command, press Esc.

About the MDI Line DRO Field

The MDI Line DRO field allows you to send commands (or, manual data input) directly to PathPilot. For information, see "Manually Enter Commands" (above). The MDI Line DRO field saves up to 100 of your most recent commands, which are saved after a power cycle.

When you select the MDI Line DRO field, all keystrokes are used within the field — so, you can't jog the machine.

Admin Commands Reference

Use the following commands in PathPilot:

Admin Command	Use to...
ADMIN AUDIO	Customize the controller's audio device settings.
ADMIN CALC	Open the calculator.
ADMIN CLEAR	Clear the message history on the Status tab.
ADMIN CONFIG	Change the configuration of the PathPilot interface.
ADMIN CYCLECOUNTER	Control the cycle counters in the Tool Path display.
ADMIN DATE	Customize the controller's date and time.
ADMIN DISPLAY	Customize the controller's screen display.
ADMIN DROPBOX	Connect your controller to a Dropbox account for cloud file syncing.
ADMIN HELP	Review a list of available Admin commands.
ADMIN KEYBOARD	Customize the controller's keyboard layout.
ADMIN LOGDATA	Write the latest machine log data to a USB drive for technical support assistance.
ADMIN MEMORY	Determine how much total RAM is on your controller.
ADMIN MOUSE	Change the mouse preferences, like pointer speed and right- or left-hand button mapping
ADMIN NETWORK	Configure a Wi-Fi network.
ADMIN OPENDOORMAXRPM	Change the maximum spindle speed with the spindle cabinet door open, when using the optional Enclosure Door Switch Kit.

Admin Command	Use to...
ADMIN RESET_SOFT_LIMITS	Reset axis soft limits to machine defaults.
ADMIN SET_X_LIMIT	Set the X-axis soft limit.
ADMIN SET_Y_LIMIT	Set the Y-axis soft limit.
ADMIN SET_Z_LIMIT	Set the Z-axis soft limit.
ADMIN SETTINGS BACKUP	Create a backup of tool offset and fixture information to store externally.
ADMIN SETTINGS RESTORE	Restore tool offset and fixture information backup from an external location.
ADMIN SHOW_SOFT_LIMITS	Display the current axis soft limits on the Status tab.
ADMIN TOOLTIP DELAYMS	Set the milliseconds prior to displaying the tooltip (and then again for the expanded tooltip). The default is 1200 milliseconds.
ADMIN TOOLTIP MAXDISPLAYSEC	Limit the amount of time the expanded tooltip displays. The default is 15 seconds.
ADMIN TOUCHSCREEN	Adjust the touch screen calibration.
ADMIN VERSION	Display detailed version information on the Status tab.

7.5.13 Copy Recently Entered Commands

- From the **MDI Line DRO** field, press either the **Up Arrow** key or the **Down Arrow** key.
The previously entered command displays.
- You must press the **Enter** key to execute the command.
To abandon the command, press **Esc**.

For information, see "Manually Enter Commands" (on the previous page).

7: PATHPILOT TOOLS AND FEATURES

7.5 Control G-Code Programs

7.5.14 Use Feeds and Speeds Suggestions



Note: Calculating feeds and speeds requires that PathPilot has relevant details about the tooling. If you haven't yet done so, go to "Create Tool Descriptions" (on the next page).

You can use PathPilot to automatically calculate feeds and speeds: from the Conversational tab, in the Conversational DROs group, select a material, a sub-type, and a tool.

1. If you haven't yet done so, enable the conversational feeds and speeds setting. From the **Settings** tab, select **Conversational Feeds and Speeds**.

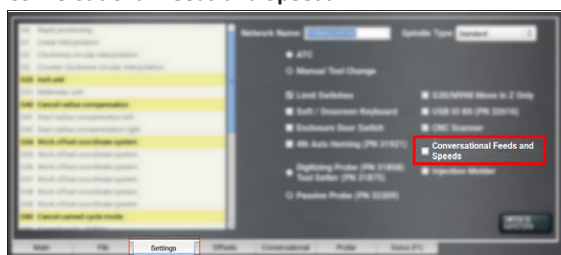


Figure 7-104: Settings tab.

2. From the **Conversational** tab, locate the **Material** dropdowns in the **Conversational DROs** group.



Figure 7-105: Feeds and speeds suggestions on the Conversational tab.

3. From the **Material** dropdown, select your material (like **Aluminum** or **Plastic**).
4. If required, from the **Sub-Type** dropdown, select the material sub-type (like **-any-** or **6061**).
5. In the **Tool** DRO field, type the assigned tool number.
6. Select **Refresh** (to the right of the **Sub-Type** dropdown). The following machining-related DRO fields are calculated:

- Spindle RPM
- Feedrate
- Z Feedrate

- Depth of Cut
- Stepmover
- Peck (if drilling)



Note: After PathPilot calculates values for the machining-related DRO fields, the background turns green.

7. (Optional) You can adjust the values in the calculated DRO fields. Adjusting the value in one of these DRO field doesn't change the value in the other machining-related DRO fields.



Note: Once you adjust the value in the DRO field, the background switches from green back to white. This helps you identify which DRO fields have suggested values (those with a green background), and which DRO fields have values you've supplied (white background).

Refresh DRO Field Values

The suggested values are no longer valid if:

- You select different material or sub-type values, or if you type a new value in to the Tool DRO field. The suggested feeds and speeds are made by taking into account all of these values. Changing any value requires you to refresh.
- You select a different Conversational tab. The suggested feeds and speeds are made by taking into account the current, specific conversational operation. Changing your conversational operation requires you to refresh the feeds and speeds values.

When the feeds and speeds are no longer valid, the Refresh button turns green, and the machining-related DRO field backgrounds switch from green to white, as shown in the following image.

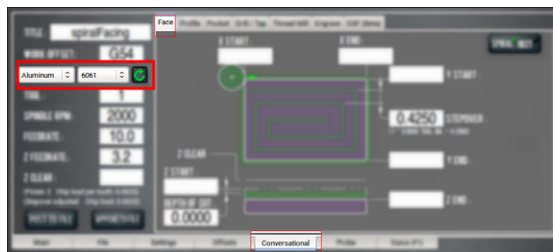


Figure 7-106: Refresh button on the Conversational tab.

Use Additional Provided Information

The following tips are displayed based on the calculations that PathPilot is performing:

- Chip Load Information** Chip load — the amount of material removed per tooth — is based on the number of flutes, RPM, and feed rate.
 Chip thinning takes the stepover (the horizontal depth of cut into the workpiece) into account, and provides the actual chip load.
 As the stepover value decreases, the actual chip load decreases. If the stepover is too small, the cutter may not have enough contact with the material to cut — effectively resulting in premature tool wear.
- Cutting Speed Information** Cutting speed is the speed that a given tooth (flute) on the cutter will be moving when it cuts through the material. All materials have a documented cutting speed.
 In imperial units, cutting speed is measured as surface feet per minute (SFM).
 In metric units, cutting speed is measured as surface meters per minute (SMM).
- Material Removal Information** The material removal rate (MRR) indicates how much material is removed by the tool per minute while cutting.
 In imperial units, cutting speed is measured as cubic inches per minute.
 In metric units, cutting speed is measured as cubic centimeters per minute.

Create Tool Descriptions

If desired, you can create tool descriptions in PathPilot. Detailed tool descriptions allow you to receive feeds and speeds suggestions in conversational programming. For information, see "Use Feeds and Speeds Suggestions" (on the previous page).

Manually Enter Tool Descriptions

PathPilot uses keywords and patterns in the tool description to recognize tooling features. For information, see "Tool Keywords Reference" (on the next page).

To manually enter tool descriptions:

- From the PathPilot interface, on the **Offsets** tab, identify the **Tool Table** window.
- Select a blank line.
- Type a description for the tool. Descriptions are not case

sensitive.

If a pattern or word in the description is recognized, PathPilot uses syntax highlighting to indicate a valid description.

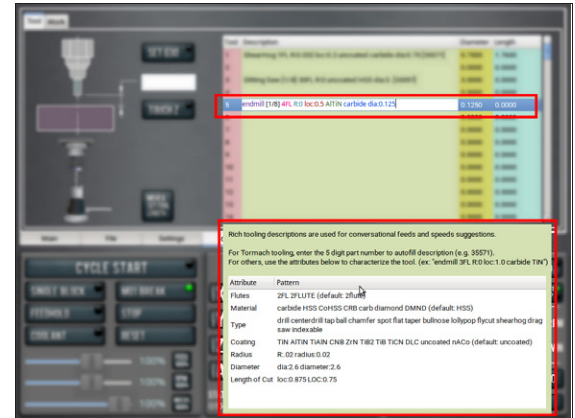


Figure 7-107: A manually-entered tool description.

Examples

To get accurate machining information, all tooling must be described with detail: the more detail, the better the results.



EXAMPLE

Dia.:.3125 4FL R:0.03 AITN CRB variable loc:.75

This description provides the following to PathPilot to calculate machining information:

- 0.3125 tool diameter
- Four flutes
- 0.03 radius, or "bullnose"
- Aluminum-titanium nitride coating
- Carbide
- Variable helix
- 0.75 length of cut (loc)

Using a personal description likely won't contain meaningful information for PathPilot.



EXAMPLE

Gold colored end mill from middle drawer

This description provides very little information, and PathPilot defaults to basic cutter features:

- Two flutes
- Uncoated, high-speed steel end mill
- Length of cut based on the diameter

7: PATHPILOT TOOLS AND FEATURES
7.5 Control G-Code Programs

Automatically Generate Tool Descriptions

If you're using a Tormach tool, you can enter the part number to automatically generate tool descriptions in the Tool Table window.

Note: If you don't know the part number, you can search for the tool at tormach.com.

- 1. From the PathPilot interface, on the Offsets tab, in the Tool Table window, select a blank line.
- 2. Type the part number for the tool, like 35571. The full description and tool diameter for a ShearHog (PN 35571) displays.

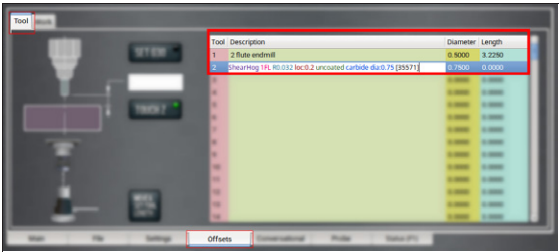


Figure 7-108: An automatically-generated tool description for a Tormach tool.

- 3. You must enter the value for the Length.

Tool Keywords Reference

PathPilot uses keywords and patterns in the tool description to recognize tooling features.

Item	Pattern	Example	Notes
type	drill, centerdrill, tap, ball, chamfer, spot, flat, taper, bullnose, lollypop, flycut, shearhog, drag, saw, indexable	DRILL, BALL, FLYCUT, DRAG	“Drag” indicates that the tool is a drag tool, and has no (0) RPM associated with it.

Item	Pattern	Example	Notes
flutes	A number followed by “FL” or “FLUTE”	4FL, 12FL, 2FLUTE	No flutes is specified the same as two flutes.
length of cut (or flute length)	“loc” followed by a colon, followed by a decimal number	LOC:0.875	If no length of cut is specified, a length is assumed based on cutter diameter.
tool coating	TiN, AlTiN, TiAlN, CNB, ZrN, TiB2, TiB, TiCN, DLC, uncoated, nACo	TiN, ZRN, TiB2	No coating is specified same as “uncoated.”
tool diameter	“diameter” or “dia” followed by a colon, followed by a decimal number	DIAMETER:.0341, DIA:.750	—
tool material	carbide, HSS, CoHSS, CRB, carb, diamond, DMND	HSS, COHSS, CRB	No tool material is specified the same as HSS (high-speed steel).

Item	Pattern	Example	Notes
tool radius	“R” or “radius” followed by a colon, followed by a decimal number	R: .02, RADIUS:0.02	No radius is specified the same as a zero radius.

7.5.15 Use Cycle Counters (M30 and M99)

On the Main tab, the Tool Path display shows M30 and M99 cycle counters. They're useful to count parts completed during unattended operation. For each M-code, there's an A and B counter. This provides more flexibility, because you can reset them to 0 independently.

For example, you could use M30 A to count parts each shift, and M30 B to count parts each week. The cycle counters persist across the controller's power cycles.

Monitor Cycle Counters

- In the **MDI Line** DRO field, type `ADMIN CYCLECOUNTER` to show or hide the counters and to reset them to 0.

Change Cycle Counter Values

The cycle counters are implemented as read-only persistent G-code numbered parameters, as detailed in the following table.

If needed, the cycle counter value can be read in G-code.

Cycle Counter	Parameter
M30 A	#5650
M30 B	#5651
M99 A	#5652
M99 B	#5653

To change a counter value explicitly, use a G10 command: `G10 L99 P~ Q~`

- P~ selects the cycle counter to change. Use any of the values detailed in the following table.

Cycle Counter	P~
M30 A	0
M30 B	1

Cycle Counter	P~
M99 A	2
M99 B	3

- Q~ specifies the value to set the cycle counter. If Q~ is omitted, the cycle counter is incremented by 1. For example, if you program `G10 L99 P2`, the M99 A cycle counter increments by 1.

7: PATHPILOT TOOLS AND FEATURES
7.6 System File Management

7.6 SYSTEM FILE MANAGEMENT

To keep the files on your system backed up and organized, use the following controls:

7.6.1 Manage System Files.....164
7.6.2 Create Backup Files..... 164
7.6.3 Restore Backup Files..... 165
7.6.4 Import and Export the Tool Table..... 166

7.6.1 Manage System Files

Use the File tab to manage system files on the PathPilot controller. For information, see "Transfer Files to and From the Controller" (page 174).

To manage system files:

- From the PathPilot interface, on the File tab, do any of the following from the Controller Files window:
- Select a file, and then select New Folder, Rename, or Delete.
- Select a file, and go to the Options menu. Then, select Copy, Cut, or Paste.

To navigate through the system files:

- Select Back or Home.

7.6.2 Create Backup Files

- 1. Insert a blank, formatted USB drive into the PathPilot controller.

Note: To prevent errors when backing up and restoring files, only use a blank, formatted USB drive.

- 2. From the PathPilot interface, on the Main tab, in the MDI Line DRO field, type ADMIN SETTINGS BACKUP. Then select the Enter key. PathPilot generates a backup .zip file, and the Admin Settings Backup dialog box displays.

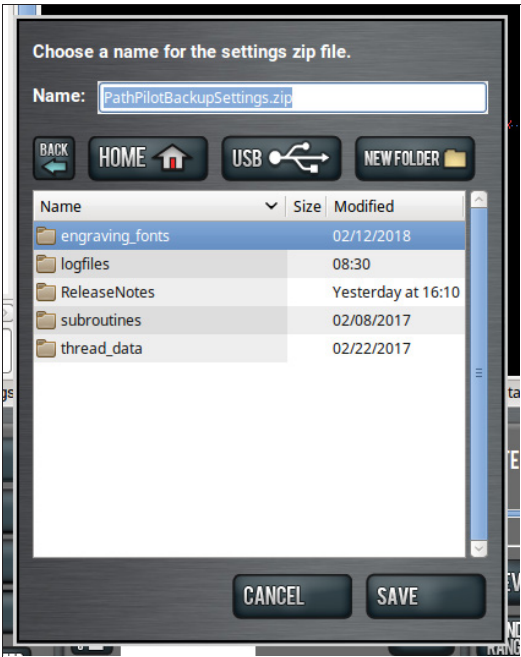


Figure 7-109: Admin Settings Backup dialog box.

- 3. From the Admin Settings Backup dialog box, specify where (on the PathPilot controller or on a USB drive) to save the backup .zip file.
- 4. Select Save. The backup .zip file is saved in the location you specified in Step 3.
- 5. If you saved the backup .zip file on the PathPilot controller, you must manually transfer it — along with other files you want to back up (like G-code programs) — to a USB drive. From the PathPilot interface, on the File tab, in the Controller Files window, select the backup .zip file and any other files you want to back up.

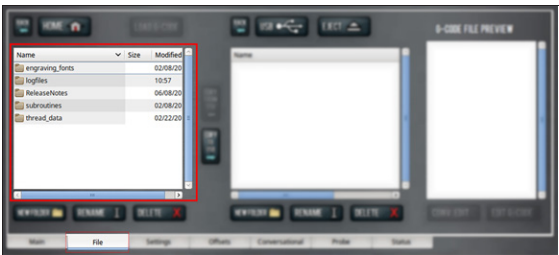


Figure 7-110: Controller Files window on the File tab.

Note: Files must have unique names. If they don't, PathPilot prompts you to overwrite or rename files, or cancel the file transfer.

6. To prevent errors, make sure you don't include the following folders:
 - **logfiles**
 - **media**
 - **ReleaseNotes**
 - **subroutines**
 - **USB**
7. Select **Copy to USB**.
The files are copied and display in the **USB Files** window.
8. Eject the USB drive from the PathPilot controller.
9. From the PathPilot interface, select **Exit**.
10. Verify that all files are properly saved: insert the USB drive on a device other than the PathPilot controller, and review the list of files on the USB drive.
11. (Optional) As an extra precaution, copy all the files onto the device.

About Backup Files

Make a regular backup of all tool offset and fixture information and machine settings stored on your PathPilot controller. Store the file externally to use if you replace your controller or restore it to factory settings.

7.6.3 Restore Backup Files

1. Insert the USB drive with your backup files into the PathPilot controller.
2. From the PathPilot interface, on the **Main** tab, in the **MDI Line DRO** field, type **ADMIN SETTINGS RESTORE**. Then select the **Enter** key.
The **Admin Settings Restore** dialog box displays.

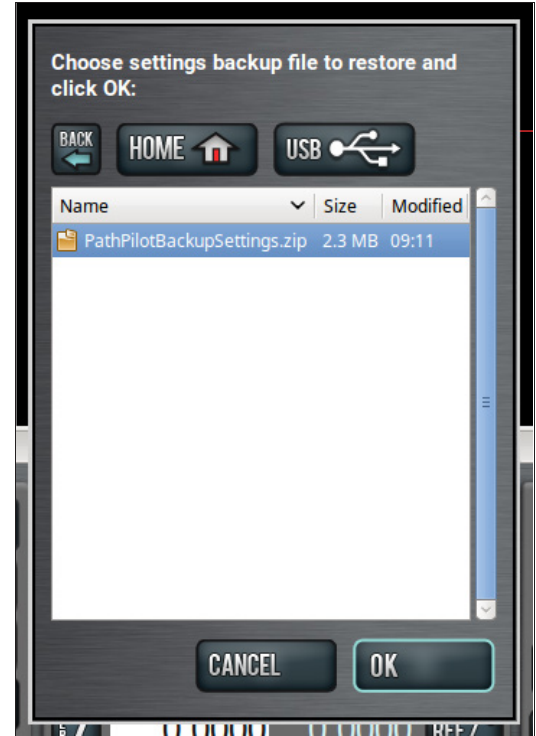


Figure 7-111: Admin Settings Restore dialog box.

3. From the **Admin Settings Restore** dialog box, navigate to the backup .zip file on the USB drive, and then select **OK**. The PathPilot operating system restores the backup, then restarts.
4. If you backed up any other files onto the USB drive, you must manually transfer the files to the PathPilot controller. From the PathPilot interface, on the **File** tab, in the **USB Files** window, select the files you want to transfer.

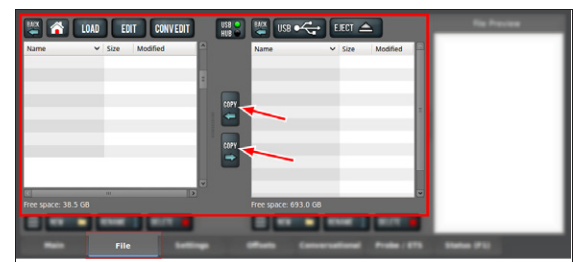


Figure 7-112: USB Files window on the File tab.



Note: To navigate backward, select **Back**. To navigate to the top level, select **USB**.

5. From the **Controller Files** window, select the folder into which you want to copy the files.

7: PATHPILOT TOOLS AND FEATURES

7.6 System File Management

6. Select **Copy From USB**.

The files display in the **Controller Files** window.



Note: Files must have unique names. If they don't, PathPilot prompts you to overwrite or rename files, or cancel the file transfer.

7.6.4 Import and Export the Tool Table

You can manage the tool table using an external .csv file.

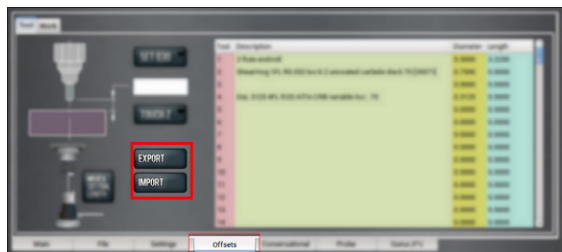


Figure 7-113: Export and Import buttons on the Offsets tab.

Import a .csv File

1. Transfer the .csv file to a USB drive.
2. Insert the USB drive into the PathPilot controller.
3. Confirm that the PathPilot controller is on.
4. From the **Offsets** tab, select **Import**.

The **Import** dialog box displays.

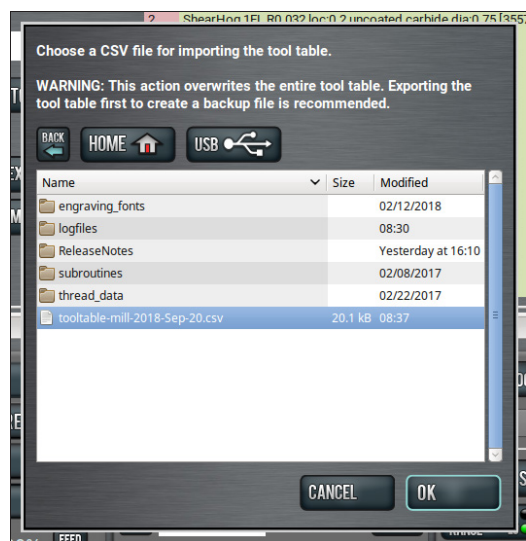


Figure 7-114: Import dialog box.

5. Navigate to the .csv file on the USB drive. Then, select **OK**.

The .csv file updates the tool table.

Export the Tool Table as a .csv File

1. From the **Offsets** tab, select **Export**.

PathPilot generates the .csv file, and the **Export** dialog box displays.

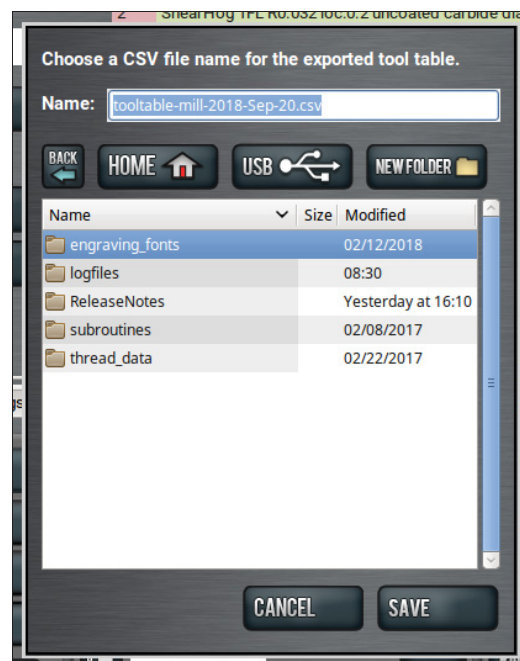


Figure 7-115: Export dialog box.

2. In the **Name** DRO field, type the name for the .csv file.
3. Select **Save**.
The .csv file is saved in the **File** tab.
4. From the **File** tab, select the newly created .csv file, and then select **Copy to USB**.
5. Select **Eject**.
It's safe to remove the USB drive from the controller.

BASIC OPERATIONS

IN THIS SECTION, YOU'LL LEARN:

- About the basic operations required for most projects, organized as a suggested project workflow.

CONTENTS

8.1 Start the Machine.....	168
8.2 Bring the Machine Out of Reset.....	169
8.3 Reference the Machine.....	170
8.4 Jog the Machine.....	171
8.5 Manually Control the Spindle.....	173
8.6 Load G-Code.....	174
8.7 Set Up Tooling.....	175
8.8 Set Tool Length Offsets.....	176
8.9 Set Work Offsets.....	180
8.10 Operate the Coolant Pump.....	181

8: BASIC OPERATIONS

8.1 Start the Machine

8.1 START THE MACHINE

Power on the machine and the PathPilot controller.

1. Turn the Main Disconnect switch to **ON** on the side of the electrical cabinet.
2. Twist out the machine's red Emergency Stop button, which enables movement to the machine axes and the spindle.
3. Press the machine's Reset button (next to the Emergency Stop button).

8.2 BRING THE MACHINE OUT OF RESET

- Select **Reset**.

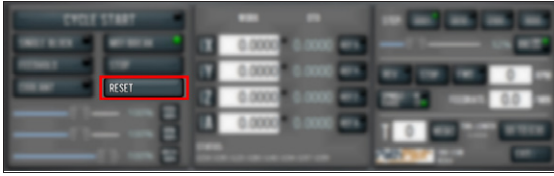


Figure 8-1: Reset button.

For more information on reset mode, see "About Reset Mode" (below).

8.2.1 About Reset Mode

When the machine is first powered on, or after an emergency stop, the Reset button flashes. When you select the flashing Reset button, PathPilot verifies communication to the machine and does the following activities:

- Brings the machine out of an emergency stop condition
- Clears alarms
- Clears the tool path backplot
- Resets all modal G-codes to their normal state
- Rewinds the currently loaded G-code program
- Stops machine motion, but is **not** a replacement for the Emergency Stop button

You can select the Reset button any time while the machine is on.

8: BASIC OPERATIONS

8.3 Reference the Machine

8.3 REFERENCE THE MACHINE



Note: The machine automatically references when it's powered on.

1. Verify that the machine can freely move to its reference position (at the ends of travel).
2. To verify that the tooling is clear of any possible obstructions, reference the Z-axis before referencing the other axes: from the PathPilot interface, select **Ref Z**.



Figure 8-2: Reference buttons.

3. Once the spindle is clear of any possible obstructions, continue referencing all axes.



Note: You can select the buttons one after another. Once the machine references one axis, it'll move on to the next.

After each axis is referenced, its button light comes on. For more information on referencing the machine, see About Referencing.

8.3.1 About Referencing

The axes are referenced during assembly and, aside from the A-axis, do not need re-referencing after powering on or once the Emergency Stop button is released. You must reference the X-, Y-, or Z-axis or the ATC at the following times:

- After replacement of a linear motion component such as linear rails, ballscrew, or servo motor
- Disconnection of an encoder battery and powering off of the machine
- Disconnection of the encoder cable from the servo motor

When referencing the X-, Y-, and Z-axis, the machine moves to the end of travel, presses against the bumper on the ballscrew until torque increases, and then backs off to the index pulse of the encoder.

You must referencing the A-axis only if the rotary table is removed from the machine.

When referencing the A-axis, the machine lines up the index marks on the body and face plate, then backs off to the index pulse of the encoder.

To reference the ATC, select the **Align Tool Tray** button on the **ATC** tab. When referencing, an ATC pocket is aligned to the flange of a tool holder in the spindle until both parts of the ATC fork open evenly when engaging the flange of the tool holder.

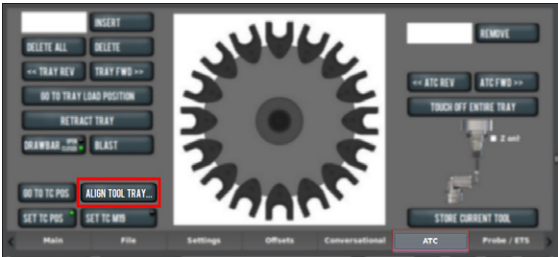


Figure 8-3: Align Tool Tray button on the ATC tab.

8.4 JOG THE MACHINE

To switch between jogging modes:

- From the **Manual Control** area, in the **Jog** group, select **Jog**.
PathPilot toggles between continuous velocity mode and step mode.



Figure 8-4: Jog button.

When the **Cont** green light is on, continuous velocity mode is selected.

When the **Step** green light is on, step mode is selected.

To use continuous velocity mode:

- Set the velocity: drag the **Jog Speed** slider.

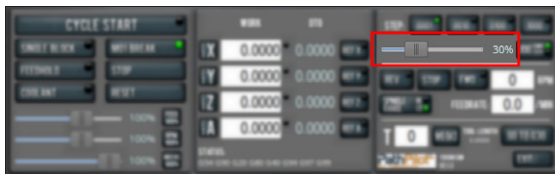


Figure 8-5: Jog Speed slider.

For more information on continuous velocity mode, see "About Continuous Velocity Jogging" (below).

To use step mode, select the step size. Do one of the following, depending on your accessories:

- In the **Manual Control Area**, in the **Jog** group, select the step size.
The **Step** button's light comes on, indicating which step size is active.



Figure 8-6: Step buttons (in G20 mode).

- On the (optional) Jog Shuttle, press the Step button to toggle the currently selected step size.
In the PathPilot interface, the **Step** button's light comes on, indicating which step size is active.

For more information on step mode, see "About Step Jogging" (below).

8.4.1 About Jogging

Jogging is the operation of manually moving an axis in various directions (like to set up and indicate fixtures or workpieces). You can't manually jog the machine while it's performing automatic operations (like running a G-code program or an MDI command).

Jog the machine using the keyboard, Jog Shuttle, or Operator Console pendant. Whichever device you're jogging with, you can either:

- Jog the machine at a consistent velocity (for information, see "About Continuous Velocity Jogging" (below)).
- Jog the machine in steps (for information, see "About Step Jogging" (below)).

For more information, see "Jog Controls Reference" (on the next page).

About Continuous Velocity Jogging

While jogging in continuous velocity mode, the machine moves at a constant speed for as long as:

- A keyboard key is pressed
- The Jog Shuttle outer ring is twisted away from the neutral position
- The Operator Console's pendant wheel is turned in the desired direction

This is useful when you're doing things like:

- Roughly positioning the machine (for example, to move the spindle head away from the workpiece).
- Moving the machine a certain distance at a constant speed (for example, to align a vise).

About Step Jogging

While jogging in step mode, the machine moves one step at a time. The jog step sizes range depending on the programming mode you are using:

- **Imperial (G20) Mode** 0.0001 in. to 0.1000 in.
- **Metric (G21) Mode** 0.01 mm to 10 mm

Step jogging mode is useful to finely move the machine, like when you're indicating a workpiece or manually setting tool lengths.

The jog keys on the keyboard only move the machine in steps when step mode is indicated in PathPilot. The inner wheel on the jog shuttle always moves the machine in steps, regardless of which mode is indicated in PathPilot. The Operator

8: BASIC OPERATIONS

8.4 Jog the Machine

Console's pendant moves the machine in the step size that's selected with the three-position switch.

8.4.2 Jog Controls Reference

The machine's jogging functions are controlled by the following:

- The Jog group of the Manual Control area in the PathPilot interface
- The keyboard
- The (optional) Jog Shuttle or Operator Console pendant

Axis	Direction	Keyboard Key	Jog Shuttle
X-Axis	Positive	Right Arrow	Clockwise
	Negative	Left Arrow	Counterclockwise
Y-Axis	Positive	Up Arrow	Clockwise
	Negative	Down Arrow	Counterclockwise
Z-Axis	Positive	Page Up	Clockwise
	Negative	Page Down	Counterclockwise
A-Axis	Positive	Period	Clockwise
	Negative	Comma	Counterclockwise

Jogging in PathPilot

From the PathPilot interface, in the Manual Control area, the Jog group has the following functions:

- The Jog button, which toggles between continuous velocity mode and step mode.
- The Jog Speed slider, which controls the machine's jog rate (whether in continuous velocity mode or in step mode).

The jog rate is measured as a percentage of the machine's maximum jog rate.

Jogging with the Keyboard

Pressing the keys results in the following actions:

- **[KEY]** jogs the axis at the current jog rate.
- **[KEY]+Shift** jogs the axis at the maximum jog rate.

Jogging with the (Optional) Jog Shuttle or Operator Console Pendant

Both the jog shuttle and operator console pendant provide manual jogging controls, but with slightly different physical interfaces:

- **Axis Movement**

- Jog Shuttle: An inner wheel provides precise, incremental jogging. Each detent (click) moves the selected axis by one jog step increment. An outer ring provides smooth, continuous jogging based on rotation speed.
- Pendant: Provides variable-speed jogging based on rotation, similar to the shuttle's outer ring.



Note: Rotating clockwise jogs the axis in the positive direction. Rotating counterclockwise jogs the axis in the negative direction.

- **Axis Selection**

- Jog Shuttle: Four buttons let you toggle between the X, Y, Z, and A axes.
- Pendant: A four-position switch selects the active axis.



Note: The currently selected axis displays in PathPilot: in the Position Status group, there's a green light to the left of the Axis DRO field. When it's on, it indicates the active axis.

- **Step Size Selection**

- Jog Shuttle: A dedicated Step button toggles between available jog step sizes.
- Pendant: A three-position switch selects the jog step size.

8.5 MANUALLY CONTROL THE SPINDLE

1. Verify that the machine is powered on and out of reset.
2. From the PathPilot interface, in the **Manual Control** area, locate the **Spindle** group.

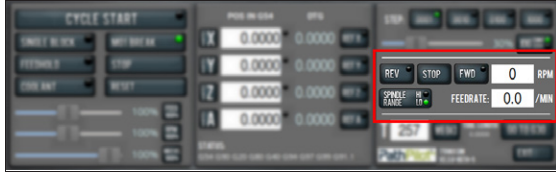


Figure 8-7: Spindle group.

3. Open the spindle motor door.
4. Make sure that the spindle belt position agrees with your desired speed range. If it doesn't, do one of the following:
 - In the PathPilot interface, select **Spindle Range**.
 - Move the spindle belt.
 For information, see Change the Spindle Speed Range.
5. Close the spindle motor door.
6. In the **RPM DRO** field, type the desired RPM speed. Then select the **Enter** key.

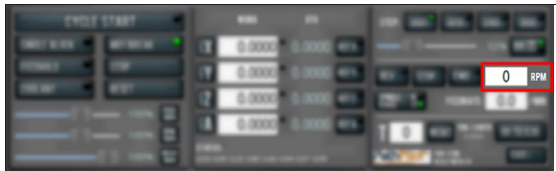


Figure 8-8: RPM DRO field.

7. Select **FWD** to start the spindle in the forward direction, or **REV** to start the spindle in the reverse direction.
8. Select **Stop** to stop the spindle.

8.5.1 About the Spindle

The machine spindle gives power to the cutting tool, which allows it to remove material from the workpiece. The spindle is driven by the spindle motor.

The machine uses a single-contact BT30 spindle taper. The tool holder contacts only the spindle taper, which keeps it in position. Because of this, there's a gap (2 mm) between the tool holder's flange and the end surface of the spindle nose.

Operate the spindle either manually or by G-code commands (entered in the MDI Line DRO field or programmed into a G-code program). Manually controlling the spindle is useful when you're setting work offsets for tools that require the spindle to be running (like “wiggler”-style edgefinders or coaxial indicators).

The machine's spindle rotates either clockwise (forward) or counterclockwise (reverse) at a specified spindle speed.

8: BASIC OPERATIONS

8.6 Load G-Code

8.6 LOAD G-CODE

To run a G-code program on a PathPilot controller, you must first verify that the file is on the controller. For more information on transferring and moving files, see "Transfer Files to and From the Controller" (below).

To load G-code:

- 1. From the **File** tab, in the **Controller Files** window, select the desired .nc file.
- 2. Select **Load**.

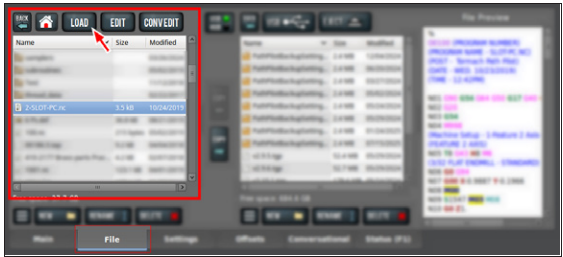


Figure 8-9: Controller Files window on the File tab.



Note: This function is only available for files stored on the PathPilot controller.

PathPilot loads the G-code file and opens the **Main** tab.

8.6.1 Transfer Files to and From the Controller

To run a G-code program, you must transfer the files to the PathPilot controller. You can either use a USB drive or PathPilot HUB (our cloud-based simulator) to transfer files. For more information on PathPilot HUB, go to hub.pathpilot.com.

To transfer files to and from the controller:

- 1. Either insert a USB drive into any open USB port, or sign in to PathPilot HUB.
- 2. From the **File** tab, select the file to transfer (either in the **USB / HUB Files** window or the **Controller Files** window).

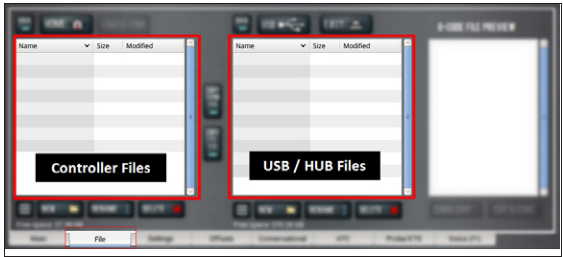


Figure 8-10: File tab.



Note: Select **Back** to move backward and either **Home** or **USB** to move to the highest level.

- 3. Select the location to which you want to copy the transferred file.
- 4. Select either **Copy ←** or **Copy →**.



Figure 8-11: File tab.



Note: The file must have a unique name. If it doesn't, you must either overwrite the file, rename the file, or cancel the file transfer.

- 5. If you're using a USB drive, select **Eject**.
It's safe to remove the USB drive from the controller.

8.7 SET UP TOOLING

Before you begin machining, you must put your cutting tools in tool holders and measure the tool length offsets for each tool.

8.7.1 Install a Tool in a Set Screw Tool Holder

1. Clean the shank of the tool holder with a clean rag. Verify that the shank is free of any grease or oil.
2. Remove the set screw from the tool holder with a hex wrench.
3. Put the desired cutting tool into the tool holder.
4. Replace the set screw in the tool holder, and then completely tighten it with a hex wrench.

8.7.2 Install a Tool in an ER Collet Tool Holder

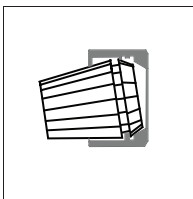
The ER20 collet is self-extracting: the collet must be mounted in the nut before the nut and collet assembly are put into the collet holder.

If you look closely, you'll notice that the collet nut isn't symmetrical — an area of the retaining ring is cut away. When the collet is correctly mounted in the nut, the collet is pushed forward and out of the collet holder taper while the nut is slightly loosened (which results in self-extraction).

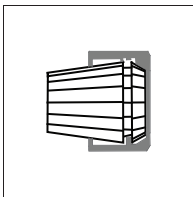
NOTICE! If you don't install the collet in the order specified, there's a risk that the collet and/or nut could be damaged, and the collet's holding capacity could be reduced.

To install a tool in an ER collet tool holder:

1. Hold the collet at an angle, and then insert it into the collet nut as shown in the following image.



2. Tilt up the collet to snap it into place.



3. Loosely thread the nut on the tool holder, insert the tool, and then tighten the collet.

8.7.3 Install a Drill Chuck in a Jacobs Taper Arbor

1. Assemble the drill chuck on to the Jacobs taper arbor:
 - a. Use a clean rag and acetone to clean the taper and socket. Verify that the taper and socket are both free of any grease or oil.
 - b. Retract the jaws: fully open the drill chuck.
 - c. Use a dead-blow hammer (or similar) to seat the drill chuck on the Jacobs taper arbor.
2. Put the drill into the drill chuck.
3. Depending on the type of drill chuck, do one of the following:
 - **Keyless Drill Chuck** Tighten the drill chuck by hand.
 - **Keyed Drill Chuck** Use a chuck key to tighten the drill chuck until it is finger tight.

8: BASIC OPERATIONS
8.8 Set Tool Length Offsets

8.8 SET TOOL LENGTH OFFSETS

Before running a G-code program, PathPilot must know the length of the tools that are required for the program. For more information on using tool length offsets, see "About Tool Offsets" (below).

Note: You can import a .csv file with tool length offset data. For information, see "Import and Export the Tool Table" (page 166).

To set tool length offsets:

- 1. Verify that the machine is powered on and out of reset.
- 2. Put a tool into a tool holder, and set it aside to measure. For information, see "Set Up Tooling" (on the previous page).
- 3. From the PathPilot interface, on the Offsets tab, verify that the Tool tab is selected.
- 4. Find the Tool Table window.

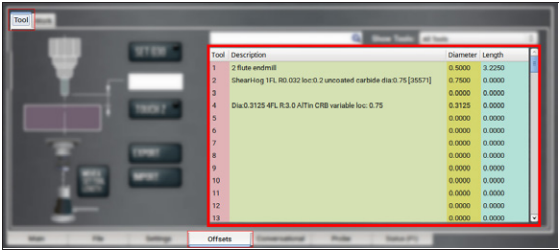


Figure 8-12: Tool Table window on the Offsets tab.

- 5. Depending on your workflow, you can measure your tools using any of the following methods:
 - Use a Tool Height Setter For information, see "Use a Tool Height Setter to Measure Tools" (page 178).
 - Use an Electronic Tool Setter For information, see "Use an Electronic Tool Setter (ETS) to Measure Tools" (page 178).
 - Touch Off of a Known Reference Height For information, see "Touch Off the Tool Length Offsets" (below).

8.8.1 About Tool Offsets

Tool offsets allow you to use various tools while still programming with respect to the workpiece. Tools can have different lengths (and, while using cutter radius compensation, different diameters).

The most common tool offset is the tool length offset: when you change tools, PathPilot must account for the difference in tool length. In CNC machines, the tool length offset is applied using a G43 command.

The tool length offset is the distance from the cutting edge of the tool to the shoulder of the tool holder.

Before you begin a G-code program, you must verify the lengths of the tools in the program, and make sure that the lengths agree with the tool length offsets set in PathPilot:

- Each time you change tools, you must apply a new tool length offset in PathPilot.
- Each time you replace a tool, you must remeasure its length, and apply a new tool length offset in PathPilot.

NOTICE! You must always verify that the physical length of a tool agrees with the tool length offset value set in PathPilot. If you don't, there's a risk that the tool length offset misrepresents the currently active tool in the spindle, which may result in a machine crash or damaged tooling, workpieces, or fixtures.

8.8.2 Touch Off the Tool Length Offsets

Touch off the tool length offsets by using a reference surface with a known height, which gives you a basis to measure any other tool lengths. Use any surface that is parallel (within 0.02 mm) to the machine table. For example:

- A 1-2-3 Block Set (PN 31950)
- Box parallel

There are two steps to touch off the tool offsets. Complete the following steps in the order listed:

Set a Known Reference Height 176
Measure Tools Using a Known Reference Height177

Set a Known Reference Height

This procedure sets a new Z zero position for the currently selected work offset.

To set a known reference height:

- 1. Identify a precision surface to use as a reference surface (like a 1-2-3 Block Set), and put it below the spindle on the machine table. Verify that there's a clear path from the spindle to the machine table.
- 2. Verify that the drive dogs won't contact the reference surface before the end face of the spindle.

3. Set a new, unused work offset (like G55). From the PathPilot interface, on the **Main** tab, in the **MDI Line** DRO field, type a work offset. Then select the **Enter** key. For information, see "Set Work Offsets" (page 180).
4. If there's already a tool in the spindle, remove it.
5. From the PathPilot interface, in the **Tool** DRO field, type 0. Then select the **Enter** key.
6. Slowly jog the Z-axis down (-Z) until it's 0.04 in. (1 mm) from the reference surface.
7. Measure the thickness of a piece of paper, and put the paper on the reference surface. Note the thickness of the paper for later.
8. While moving the paper back-and-forth across the reference surface, slowly step the Z-axis down (-Z) until you feel a light pull on the piece of paper. This indicates that the paper is contacting the end face of the spindle.



Note: It's easier to use step jogging for this task. For information on step jogging, see "About Step Jogging" (page 171).

9. From the PathPilot interface, in the **Z-axis** work offset DRO field, type the thickness of the piece of paper. Then select the **Enter** key.



Figure 8-13: Z-axis work offset DRO field.

The reference surface is now set as the Z zero position in the current coordinate system.

10. To set the tool length offset, go to Measure Tools Using a Known Reference Height.

Measure Tools Using a Known Reference Height

This procedure sets the tool length offset using a known reference height. If you have not yet done so, you must first set the Z zero position; go to Set a Known Reference Height. To measure tools using a known reference height:

1. Verify that the reference surface is still on the machine table with the piece of paper.

2. From the PathPilot interface, on the **Offsets** tab, find an unused tool number in the **Tool Table** window. Then, type a description for the tool you're measuring.
3. Put the tool holder into the spindle.
4. From the PathPilot interface, in the **Tool** DRO field, type the number of the tool. Then select the **Enter** key.



Figure 8-14: Tool DRO field.

5. Slowly jog the Z-axis down (-Z) until it is 0.04 in. (1 mm) from the reference surface.
6. Continue to slowly jog the Z-axis while slowly moving the piece of paper back-and-forth on the reference surface.
7. Stop jogging the Z-axis when you feel a light pull on the piece of paper, which indicates that it is in contact with the tool.
8. From the PathPilot interface, on the **Offsets** tab, in the **Tool Table**, select the tool for which you previously wrote a description.
9. In the **Touch Z** DRO field, type the thickness of the piece of paper. Then select the **Enter** key.

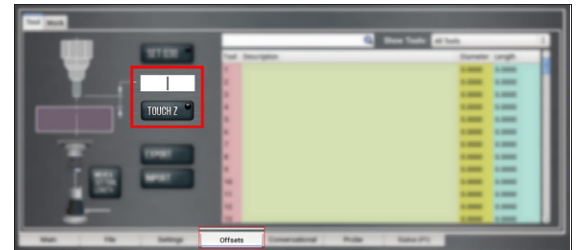


Figure 8-15: Touch Z DRO field and button.

10. Select **Touch Z**.
The length of the tool is stored in the **Tool Table** window.
11. From the **Tool Table** window, in the **Length** column, verify that the length of the tool is correct.
12. In the **Diameter** column, type the diameter of the tool. Then select the **Enter** key.

8: BASIC OPERATIONS
8.8 Set Tool Length Offsets

- 13. Jog the Z-axis up (+Z).
You've completed the procedure to measure a tool offset. Repeat this procedure for any remaining tooling you have. Once you're done adding tool length offsets, switch back to your work coordinate system.

8.8.3 Use an Electronic Tool Setter (ETS) to Measure Tools

An ETS is a device used to measure the length of a cutting tool. To use an ETS to measure tools:

- 1. Put the ETS on the known reference surface below the spindle.
- 2. From the PathPilot interface, on the Offsets tab, in the Tool Table window, in the Description column, type a description for the tool.
- 3. In the Diameter column, type the diameter of the tool. Then select the Enter key.
- 4. Put a tool holder into the spindle.
- 5. From the PathPilot interface, type the tool number in the Tool DRO field. Then select the Enter key.



Figure 8-16: Tool DRO field.

- 6. Jog the Z-axis down (-Z) until it is above the ETS.
- 7. From the Offsets tab, on the Tool tab, select Move and Set Tool Length.

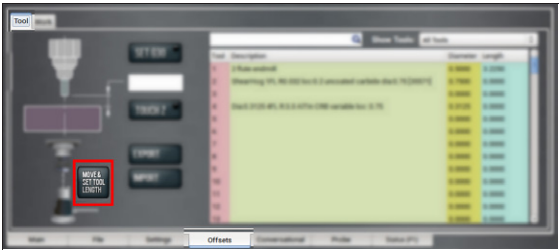


Figure 8-17: Tool tab on the Offsets tab.

Note: Regardless of the initial feed rate, the final touch off feed rate while using an ETS is 2-1/2 in. per minute (IPM).

- 8. From the Tool Table window, in the Length column, verify that the length of the tool is correct.

8.8.4 Use a Tool Height Setter to Measure Tools

This procedure sets the tool length offset using a known reference height and a Tool Height Setter (PN 39682). Complete the following steps in the order listed:

- Set a Known Reference Height 178
- Verify the Calibration of the Tool Height Setter..... 179

Set a Known Reference Height

This procedure sets a new Z zero position for the currently selected work offset.

To set a known reference height:

- 1. Identify a precision surface to use as a reference surface (like a 1-2-3 Block Set), and put it below the spindle on the machine table. Verify that there's a clear path from the spindle to the machine table.
- 2. Set a new, unused work offset (like G55). From the PathPilot interface, on the Main tab, in the MDI Line DRO field, type a work offset. Then select the Enter key. For information, see "Set Work Offsets" (page 180).
- 3. If there's already a tool in the spindle, remove it.
- 4. From the PathPilot interface, in the Tool DRO field, type 0. Then select the Enter key.
- 5. Slowly jog the Z-axis down (-Z) until it's 0.04 in. (1 mm) from the reference surface.
- 6. Measure the thickness of a piece of paper, and put the paper on the reference surface. Note the thickness of the paper for later.
- 7. While moving the paper back-and-forth across the reference surface, slowly step the Z-axis down (-Z) until you feel a light pull on the piece of paper. This indicates that the paper is contacting the end face of the spindle.

Note: It's easier to use step jogging for this task. For information on step jogging, see "About Step Jogging" (page 171).

- From the PathPilot interface, in the **Z-axis** work offset DRO field, type the thickness of the piece of paper. Then select the **Enter** key.



Figure 8-18: Z-axis work offset DRO field.

The reference surface is now set as the Z zero position in the current coordinate system.

Verify the Calibration of the Tool Height Setter

The higher side of the Tool Height Setter is precision ground. You can use it as a reference surface to calibrate the tool.



Figure 8-19: Tool Height Setter.

- Use the provided dowel pin to compress the setting face of the Tool Height Setter to the level of the ground reference surface.
- Adjust the indicator dial's bezel to read zero. Make note of how many times the indicator rotates around the dial.
- Measure the height of the ground reference surface from the bottom surface of the Tool Height Setter with a calipers. Note the measured height for later.
- Carefully, without moving the bezel, put the Tool Height Setter on the reference surface that's on the machine table.
- Measure the tools using a known reference height.

8: BASIC OPERATIONS

8.9 Set Work Offsets

8.9 SET WORK OFFSETS

To set the current axis location to zero in the active work coordinate system:

- Select **Zero [Axis]**.

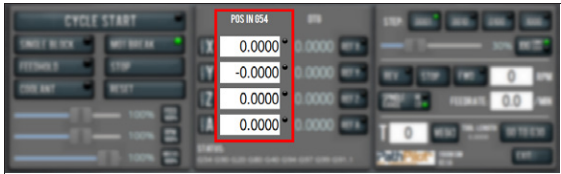


Figure 8-20: Work Offset DRO fields.

To change work offsets:

1. On the **Main** tab, in the **MDI Line DRO** field, type the new work offset to activate (for example, G55). Then select the **Enter** key.
2. The new work offset displays in the following locations in the PathPilot interface:
 - The **Status** read-only DRO field.
 - Above the **Work Offset** DRO fields.

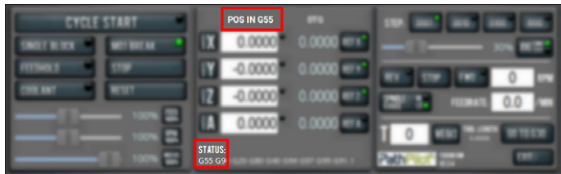


Figure 8-21: Work offset indicated in the PathPilot interface.

Note: The values in the **Work Offset** DRO fields update to indicate the new location of each axis in the new work offset.

Work Offset Naming		
Offsets 1-9 (Use either name)		
Offset	Extended Name	Name
1	G54.1 P1	G54
2	G54.1 P2	G55
3	G54.1 P3	G56
4	G54.1 P4	G57
5	G54.1 P5	G58
6	G54.1 P6	G59
7	G54.1 P7	G59.1
8	G54.1 P8	G59.2
9	G54.1 P9	G59.3
Offsets 10-500 (Use extended name)		
Offset	Extended Name	Name
10	G54.1 P10	Not used
11	G54.1 P11	Not used
...		
499	G54.1 P499	Not used
500	G54.1 P500	Not used

For more information on using work offsets, see "About Work Offsets" (below).

8.9.1 About Work Offsets

Work offsets allow you to think in terms of X, Y, and Z coordinates with respect to the part, rather than thinking of them with respect to the machine position. This means that you can jog the machine to an arbitrary location (like the end of a workpiece) and call that location zero. You can save up to 500 work offsets in PathPilot. The naming structure varies based on the offset number, as detailed in the following table.

8.10 OPERATE THE COOLANT PUMP

To turn coolant on or off:

- Select **Coolant**.

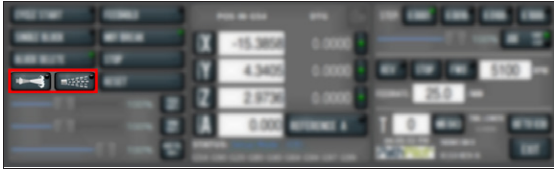


Figure 8-22: Coolant button.

For more information on turning on and off coolant, see "About Coolant" (below).

8.10.1 About Coolant

In the PathPilot interface, the Coolant button controls the machine's coolant pump power outlet. The Coolant button's light shows the current state of the outlet: the light is on when the outlet has power; the light is off when the outlet does not have power.



Note: The Coolant button is equivalent to using an M08 (coolant on) or M09 (coolant off) command in the G-code program.

Use the Coolant button before or after a program is running, while a program is running, or while you are using manual data input (MDI) commands.



PROGRAMMING

IN THIS SECTION, YOU'LL LEARN:

- About the languages that are understood and interpreted by PathPilot.

CONTENTS

9.1 Programming Overview.....	184
9.2 Programming G-Code.....	190
9.3 Programming Canned Cycles.....	202
9.4 Programming M-Code.....	207
9.5 Programming Input Codes.....	211
9.6 Advanced Programming.....	212

9: PROGRAMMING

9.1 Programming Overview

9.1 PROGRAMMING OVERVIEW

Read the following sections for a G-code overview:

9.1.1 About G-Code Programming Language.....	184
9.1.2 G-Code Formatting Reference.....	184
9.1.3 Supported G-Codes Reference.....	188

9.1.1 About G-Code Programming Language

A G-code program is made up of one or more lines of code. Each line of code is called a block, and can include commands to the machine. Blocks are collected into a file, which makes a program.

A block is normally made up of an optional line number at the beginning, followed by one or more words, which groups the elements together into a single statement.

A word is a letter followed by a number (or, something that evaluates to a number). A word can either give a command or provide an argument to a command.

A program is one or more blocks, each separated by a line break. Blocks in a program are executed either:

- Sequentially (from the top of the program to the bottom)
- Until an end command (M02 or M30) is encountered

EXAMPLE :

G01 X3 is a valid line of code with two words:

- G01 is a command: the machine should move in a straight line at the programmed feed rate.
- X3 provides an argument value: the value of X should be 3 at the end of the move.

Most commands start with either G (general) or M (miscellaneous) — G-codes and M-codes.

There are two commands (M02 and M30) that end a program. A program can end before the end of a file. If there are lines in a file after the end of a program, they're not meant to be executed in the normal flow (they're generally parts of subroutines).

9.1.2 G-Code Formatting Reference

A permissible block of input code is made up of the following programming elements, in order, with the restriction that there is a maximum of 256 characters allowed on a line:

1. (Optional) Block delete character (/)
2. (Optional) Line number

3. Any number of words, parameter settings, and comments
4. End of line marker (carriage return or line break)

Spaces and tabs are allowed anywhere on a line of code and do not change the meaning of the line, except inside comments. Blank lines are allowed in the input, but they're ignored. Input is not case sensitive (except in comments), so any letter outside a comment may be in uppercase or lowercase without changing the meaning of a line.

EXAMPLE

G00 x +0.1234y 7 is equal to G00 x+0.1234 y7

A line may have:

- Any number of G words, but two G words from the same modal group may not appear on the same line.
- Zero to four M words, but two M words from the same modal group may not appear on the same line.
- For all other legal letters, a line may have only one word beginning with that letter.

Any input not explicitly allowed is illegal, and causes the interpreter to either signal an error or ignore the line.

PathPilot omits blocks of code that are prefixed with a block delete character (/).

PathPilot sometimes ignores things it doesn't understand. If a command doesn't work as expected, or does nothing, make sure that it's correctly typed. PathPilot doesn't check for excessively high machining feeds or speeds, and it doesn't detect situations where a legal command will do something unfortunate (like machining a fixture).

Line Numbers

A line number is indicated by the following, in the order listed:

1. The letter N
2. An integer (with no sign) between 0 and 99,999,999 (which must be written without commas)

Line numbers may be repeated, or used out of order, but that's rare in normal practice. A line number isn't required, and is often omitted.

Words

A word is indicated by the following, in the order listed:

1. A letter other than N or O
2. A real value

Letters

Words may begin with any of the following letters, except N or O:



Note: Several letters (I, J, K, L, P and R) may have different meanings in different contexts.

Letter	Description
A	A-axis
B	B-axis
C	C-axis
D	Tool radius compensation number
F	Feed rate
G	General function
H	Tool length offset index
I	X-axis offset for arcs
J	Y-axis offset for arcs
K	Z-axis offset for arcs
L	Number of repetitions in canned cycles and subroutines, or key used with G10
M	Miscellaneous function
N	Line number
O	Subroutine label number
P	Dwell time in canned cycles, dwell time with G04, key used with G10, or tapping depth in M871 through M874
Q	Feed increment in a G83 canned cycle, or repetitions of subroutine call
R	Arc radius, or canned cycle retract level
S	Spindle speed
T	Tool selection
U	Synonymous with A
V	Synonymous with B
W	Synonymous with C

Letter	Description
X	X-axis
Y	Y-axis
Z	Z-axis

Values

A real value is one of the following:

- An explicit number (like 341, or -0.8807)
- An expression (like [2+2.4])
- A parameter value (like #88)
- A unary operation value (like acos[0])



Note: In the command examples that we use, the tilde symbol (~) stands for a real value. If $L\sim$ is written in an example, the ~ is often referred to as the L number. Similarly the ~ in $H\sim$ may be called the H number, and so on for any other letter.

A number is a subset of a real value. Processing a real value to come up with a number is called evaluating. An explicit number evaluates to itself.

Explicit numbers have the following rules (in this case, a digit is a single character, 0 through 9):

- A number must consist of the following, in the order listed:
 1. An optional plus or minus sign
 2. Zero to many digits
 3. (Optional) One decimal point
 4. Zero to many digits
- There must be at least one digit somewhere in the number.
- It must be either an integer (no decimal point) or a decimals (decimal point).
- It may have any number of digits (subject to line length limitations).



Note: PathPilot only keeps 17 significant figures, which is enough for all known applications.

- A non-zero number with no sign as the first character is assumed to be positive.

9: PROGRAMMING

9.1 Programming Overview

Initial zeros (a zero before the decimal point and the first non-zero digit) and trailing zeros (a zero after the decimal point and the last non-zero digit) are allowed, but not required. A number written with initial or trailing zeros has the same value when it is read as if the extra zeros were not there. Numbers used for specific purposes by PathPilot are often restricted to some finite set of values, or to some range of values. In many uses, decimal numbers must be close enough to an integer to be accepted as a valid input. A decimal number which is supposed to be close to an integer is considered close enough if it is within 0.0001 of an integer.

Order of Execution

If a parameter setting of the same parameter is repeated on a line (like #3=15 #3=6), only the last setting takes effect. It's illogical, but not illegal, to set the same parameter twice on the same line.

The order of items on a line doesn't determine the order of execution on the commands.

Three types of items' order may vary on a line (as given earlier in this section):

- **Word** May be reordered in any way without changing the meaning of the line.
- **Parameter Setting** If it's reordered, there is no change in the meaning of the line unless the same parameter is set more than once. In this case, only the last setting of the parameter takes effect.



EXAMPLE

When the line #3=15 #3=6 is interpreted, the value of parameter 3 is 6. If the order is reversed to #3=6 #3=15 and the line is interpreted, the value of parameter 3 is 15.

- **Comment** If it contains more than one comment and is reordered, only the last comment is used. If each group is kept in order or reordered without changing the meaning of the line, then the three groups may be interleaved in any way without changing the meaning of the line.



EXAMPLE

G40 G01 #3=15 (foo) #4=-7.0 has five items and means exactly the same thing in any of the 120 possible orders, like #4=-7.0 G01 #3=15 G40 (foo), for the five items.

The order of execution of items on a line is critical to safe and effective machine operation. If items occur on the same line, they are executed in a particular order. To impose a different order (like to turn coolant off before the spindle is stopped), code the commands on separate blocks.

The order of execution is as follows:

1. Comment (including message)
2. Set feed rate mode (G93, G94, G95)
3. Set feed rate (F)
4. Set spindle speed (S)
5. Special I/O (M62 to M68)



Note: This is not supported.

6. Change tool (T)
7. Spindle on/off (M03, M04, M05)
8. Save State (M70, M73, restore state (M72), invalidate state (M71)
9. Coolant on/off (M07, M08, M09)
10. Enable/disable overrides (M48, M49, M50, M51, M52, M53)
11. Operator defined commands (M101 to M199)
12. Dwell (G04)
13. Set active plane (G17, G18, G19)
14. Set length units (G20, G21)
15. Cutter radius compensation on/off (G40, G41, G42)
16. Tool table offset on/off (G43, G49)
17. Fixture table select (G54 through G58 and G59 P~)
18. Set path control mode (G61, G61.1, G64)
19. Set distance mode (G90, G91)
20. Set canned cycle return level mode (G98, G99)
21. Home, change coordinate system data (G10) or set offsets (G92, G94)
22. Perform motion (G00 to G03, G12, G13, G80 to G89 as

modified by G53)

23. Stop (M00, M01, M02, M30, M60)

Modal Groups

G- and M-codes are, generally speaking, modal — they cause the machining system to change from one mode to another. The mode stays active until another command changes it implicitly or explicitly.



EXAMPLE

If coolant is turned on (M07 or M08), it stays on until it is explicitly turned off in the program (M09).

A few G-codes and M-codes are non-modal (like Dwell (G04)). These codes have effect only on the lines on which they occur. Modal commands are arranged in sets, called modal groups. Only one member of a modal group may be in force at any given time. In general, a modal group contains commands for which it is logically impossible for two members to be in effect at the same time (like inch units (G20) vs. millimeter units (G21)).

A machining system may be in many modes at the same time, with one mode from each modal group being in effect. For all G-code modal groups, when a machining system is ready to accept commands, one member of the modal group must be in effect. There are default settings for these modal groups. When the machining system is turned on or re-initialized, default values are automatically in effect.

Modal groups for G-codes are detailed in the following table.

Group	Commands	Group Description
Group 1	{G00, G01, G02, G03, G33, G37/G37.1, G38.x, G73, G76, G80, G81, G82, G84, G85, G86, G88, G89}	Motion (one always in effect)
Group 2	{G17, G18, G19, G17.1, G17.2, G17.3}	Plane selection

Group	Commands	Group Description
Group 3	{G90, G91}	Distance mode
Group 4	{G90.1, G91.1}	Arc distance mode
Group 5	{G93, G94}	Feed rate mode
Group 6	{G20, G21}	Length units
Group 7	{G40, G41, G42, G41.1, G42.1}	Cutter compensation
Group 8	{G43, G43.1, G49}	Tool length offset
Group 10	{G98, G99}	Return mode in canned cycles
Group 12	{G54, G55, G56, G57, G58, G59, G59.1, G59.2, G59.3}	Select work offset coordinate system
Group 13	{G61, G61.1, G64}	Path control mode
Group 14	{G96, G97}	Spindle control mode
Group 15	{G07, G08}	Lathe diameter mode

Modal groups for M-codes are detailed in the following table.

Group	Commands	Group Description
Group 4	{M00, M01, M02, M30, M60}	Program stop and program end
Group 7	{M03, M04, M05}	Spindle control
Group 8	{M07, M08, M09}	Coolant control (special case: M07 and M08 may be active at the same time)

9: PROGRAMMING

9.1 Programming Overview

Group	Commands	Group Description
Group 9	{M48, M49}	Override control

Non-modal G-codes are:

- **Group 0** {G04, G10, G28, G30, G53, G92, G92.1, G92.2, G92.3}

Comments

You can add comments to lines of G-code to help clarify the intention of the programmer. To embed a comment in a line, use parentheses. To add a comment to the end of a line, use a semicolon.



Note: The semicolon is not treated as the start of a comment when it's enclosed in parentheses.

Comments can appear between words, but they can't be between words and their corresponding parameter.



EXAMPLE :

S100 (set speed) F200 (feed) is okay, but S (speed) 100F (feed) is not.

9.1.3 Supported G-Codes Reference

G-Code	Description
G00	Rapid linear motion
G01	Linear motion at feed rate
G02	Clockwise arc at feed rate
G03	Counterclockwise arc at feed rate
G04	Dwell
G10 L1	Set tool table
G10 L2	Set coordinate system
G10 L10	Set tool table – calculated – workpiece
G10 L11	Set tool table – calculated – fixture
G10 L20	Set coordinate system
G17, G18, G19	Plane selection
G20/G21	Length units

G-Code	Description
G28	Return to predefined position
G28.1	Return to predefined position
G30	Return to predefined position
G33	Spindle synchronized motion (like threading)
G33.1	Rigid tapping
G37/G37.1	Automatically measure tool lengths with an ETS
G38.x	Straight probe
G40	Cancel cutter compensation
G41/G42	Cutter compensation (left/right)
G41.1, G42.1	Dynamic cutter compensation
G43	Apply tool length offset
G47	Engrave sequential serial number
G49	Cancel tool length compensation
G53	Absolute coordinates
G54-G59.3	Select work offset coordinate system
G61/G61.1	Set exact path control mode
G64	Set blended path control mode
G73	High-speed peck drill
G76	Multi-pass threading cycle
G80	Cancel canned cycles
G81	Drilling cycle
G82	Simple drilling cycle
G83	Peck drilling cycle
G84	Tapping cycle
G85	Boring cycle
G86	Boring cycle
G88	Boring cycle
G89	Boring cycle

G-Code	Description
<u>G90,</u> <u>G90.1</u>	Arc distance mode
G91, G91.1	Incremental distance mode
G92	Offset coordinates and set parameters
G92.x	Cancel G92, etc.
<u>G93, G94,</u> <u>G95</u>	Feed rate mode
<u>G96, G97</u>	Spindle control mode
G98	Initial level return / R-point level after canned cycles

9: PROGRAMMING

9.2 Programming G-Code

9.2 PROGRAMMING G-CODE

Read the following sections as a G-code reference:

9.2.1 About the Examples Used	190
9.2.2 Rapid Linear Motion (G00).....	190
9.2.3 Linear Motion at Feed Rate (G01).....	190
9.2.4 Arc at Feed Rate (G02 and G03).....	191
9.2.5 Dwell (G04).....	193
9.2.6 Set Offsets (G10).....	193
9.2.7 Plane Selection (G17, G18, G19).....	194
9.2.8 Length Units (G20 and G21).....	194
9.2.9 Return to Predefined Position (G28 and G28.1)....	194
9.2.10 Return to Predefined Position (G30 and G30.1)....	195
9.2.11 Automatically Measure Tool Lengths with an ETS (G37 and G37.1).....	195
9.2.12 Straight Probe (G38.x).....	196
9.2.13 Cutter Compensation (G40, G41, G42).....	197
9.2.14 Dynamic Cutter Compensation (G41.1 and G42.1).....	197
9.2.15 Apply Tool Length Offset (G43).....	198
9.2.16 Engrave Sequential Serial Number (G47).....	198
9.2.17 Cancel Tool Length Compensation (G49).....	198
9.2.18 Absolute Coordinates (G53).....	198
9.2.19 Select Work Offset Coordinate System (G54 to G54.1 P500).....	199
9.2.20 Set Exact Path Control Mode (G61).....	199
9.2.21 Set Blended Path Control Mode (G64).....	199
9.2.22 Distance Mode (G90 and G91).....	199
9.2.23 Arc Distance Mode (G90.1 and G91.1).....	199
9.2.24 Temporary Work Offsets (G92, G92.1, G92.2, and G92.3).....	199
9.2.25 Feed Rate Mode (G93, G94, and G95).....	200
9.2.26 Spindle Control Mode (G96 and G97).....	200

9.2.1 About the Examples Used

Many commands require axis words ($X\sim$, $Y\sim$, $Z\sim$, or $A\sim$) as an argument. Unless explicitly stated otherwise, you can make the following assumptions:

- Axis words specify a destination point
- Axis words relate to the currently active coordinate system, unless explicitly described as being in the absolute coordinate system
- Where axis words are optional, any omitted axes retain their current value

Any items in the command examples not explicitly described as optional are required.

9.2.2 Rapid Linear Motion (G00)

For rapid linear motion, program: $G00\ X\sim\ Y\sim\ Z\sim\ A\sim$

- $X\sim$ is the X-axis coordinate
- $Y\sim$ is the Y-axis coordinate
- $Z\sim$ is the Z-axis coordinate
- $A\sim$ is the A-axis coordinate

This produces coordinated linear motion to the destination point at the current traverse rate (or slower, if the machine won't go that fast). It's expected that cutting won't take place when a $G00$ command is executing. The $G00$ is optional if the current motion mode is $G00$.

Depending on where the tool is located, follow these two basic rules:

1. If the Z value represents a cutting move in the positive direction (like out of a hole), the X-axis should be moved last.
2. If the Z value represents a move in the negative direction, the X-axis should be moved first.

Conditions

The motion differs if:

- Cutter radius compensation is active
- G53 is programmed on the same line

Troubleshooting

It's an error if:

- All axis words are omitted
The axis words are optional, except that at least one must be used.
- $G10$, $G28$, $G30$ or $G92$ appear in the same block

9.2.3 Linear Motion at Feed Rate (G01)

For linear motion at feed rate (for cutting or not), program:

$G01\ X\sim\ Y\sim\ Z\sim\ A\sim\ F\sim$

- $X\sim$ is the X-axis coordinate
- $Y\sim$ is the Y-axis coordinate
- $Z\sim$ is the Z-axis coordinate
- $A\sim$ is the A-axis coordinate
- $F\sim$ is the feed rate

This produces coordinated linear motion to the destination point at the current feed rate (or slower, if the machine won't go that fast). The $G01$ is optional if the current motion mode is $G01$.

Conditions

The motion differs if:

- Cutter radius compensation is active
- G53 is programmed on the same line

Troubleshooting

It's an error if:

- All axis words are omitted
The axis words are optional, except that at least one must be used.
- G10, G28, G30, or G92 appear in the same block
- No F word is specified

9.2.4 Arc at Feed Rate (G02 and G03)

A circular or helical arc is specified using either G02 (clockwise arc) or G03 (counterclockwise arc). The axis of the circle or helix must be parallel to the X-, Y- or Z-axis of the machine coordinate system. The axis (or equivalently, the plane perpendicular to the axis) is selected with G17 (Z-axis, XY-plane), G18 (Y-axis, XZ-plane) or G19 (X-axis, YZ-plane). If the arc is circular, it lies in a plane parallel to the selected plane. If a line of code makes an arc and includes rotational axis motion, the rotational axes turn at a constant rate so that the rotational motion starts and finishes when the XYZ motion starts and finishes. This is rare.

The motion differs if cutter radius compensation is active.

Two formats are allowed for specifying an arc: the center format and the radius format. In both formats, the G02 or G03 is optional if it's the current motion mode.

Radius Format Arc

For a clockwise arc in radius format, program: G02 X~ Y~ Z~ A~ R~

For a counterclockwise arc in radius format, program: G03 X~ Y~ Z~ A~ R~

- X~ is the X-axis coordinate
- Y~ is the Y-axis coordinate
- Z~ is the Z-axis coordinate
- A~ is the A-axis coordinate
- R~ is the radius of the arc

In radius format, the coordinates of the end point of the arc in the selected plane are specified along with the radius of the arc. A positive radius indicates that the arc turns through 180 degrees or less, while a negative radius indicates a turn of 180 degrees to 359.999 degrees.

If the arc is helical, the value of the end point of the arc on the coordinate axis parallel to the axis of the helix is also specified. We don't recommend programming radius format arcs that are:

- Nearly full circles
- Semicircles
- Nearly semicircles

A small change in the location of the end point produces a much larger change in the location of the center of the circle (and the middle of the arc). The magnification effect is large enough that rounding error in a number can produce out-of-tolerance cuts.

You can program arcs that are:

- Up to 165 degrees
- Between 195 degrees to 345 degrees



EXAMPLE

G17 G02 X 1.0 Y 1.5 R 2.0 Z 0.5 is a radius format command to mill an arc, which makes a clockwise (as viewed from the positive Z-axis) circular or helical arc whose axis is parallel to the Z-axis, ending where X = 1.0, Y = 1.5, and Z = 0.5, with a radius of 2.0. If the starting value of Z is 0.5, this is an arc of a circle parallel to the XY-plane; otherwise, it's a helical arc.

Troubleshooting

It's an error if:

- Both of the axis words for the axes of the selected plane are omitted
The axis words are all optional except that at least one of the two words for the axes in the selected plane must be used.
- No R word is given
- The end point of the arc is the same as the current point
- G10, G28, G30, or G92 appear in the same block

Center Format Arc

For a clockwise arc in center format, program: G02 X~ Y~ Z~ I~ J~

For a counterclockwise arc in center format, program: G03 X~ Y~ Z~ I~ J~

- X~ is the X-axis coordinate
- Y~ is the Y-axis coordinate
- Z~ is the Z-axis coordinate

9: PROGRAMMING

9.2 Programming G-Code

- **A~** is the A-axis coordinate
- **I~** is the center of arc (X coordinate)
- **J~** is the center of arc (Y coordinate)
- **K~** is the center of arc (Z coordinate)

In the center format, the coordinates of the end point of the arc in the selected plane are specified along with the offsets of the center of the arc from the current location. In this format, it's okay if the end point of the arc is the same as the current point.

The center is specified using the I, J, K words associated with the active plane. These specify the center relative to the current point at the start of the arc, defined in incremental coordinates from the start point.

It's an error if:

- When the arc is projected on the selected plane, the distance from the current point to the center differs from the distance from the end point to the center by more than 0.0002 inches (if you're programming in inches) or 0.002 millimeters (if you're programming in millimeters)
- **G10**, **G28**, **G30**, or **G92** appear in the same block

Arc in XY Plane

When the XY-plane is selected, program: **G02 X~ Y~ Z~ A~ I~ J~** (or, use **G03** instead of **G02**)

I and J are the offsets from the current location or coordinates – depending on arc distance mode (G90.1/G91.1) of the center of the circle (X and Y directions, respectively).

It's an error if:

- X and Y are both omitted
The axis words are all optional except that at least one of X and Y must be used.
- I and J are both omitted
I and J are optional except that at least one of the two must be used.

Arc in XZ Plane

When the XZ-plane is selected, program: **G02 X~ Y~ Z~ A~ I~ K~** (or, use **G03** instead of **G02**)

I and K are the offsets from the current location or coordinates – depending on arc distance mode (G90.1/G91.1) of the center of the circle (X and Z directions, respectively).

It's an error if:

- X and Z are both omitted
The axis words are all optional except that at least one of X and Z must be used.
- I and K are both omitted
I and K are optional except that at least one of the two must be used.

Arc in YZ Plane

When the YZ-plane is selected, program: **G02 X~ Y~ Z~ A~ J~ K~** (or, use **G03** instead of **G02**)

J and K are the offsets from the current location or coordinates – depending on depending on arc distance mode (G90.1/G91.1) of the center of the circle (Y and Z directions, respectively).

It's an error if:

- Y and Z are both omitted
The axis words are all optional except that at least one of Y and Z must be used.
- J and K are both omitted
J and K are optional except that at least one of the two must be used.



EXAMPLE

G17 G02 X1.0 Y1.6 I0.3 J0.4 Z0.9 is a center format command to mill an arc in incremental arc distance mode (G91.1) that makes a clockwise (as viewed from the positive Z-axis), circular, or helical arc whose axis is parallel to the Z-axis, ending where X = 1.0, Y = 1.6, and Z = 0.9, with its center offset in the X direction by 0.3 units from the current X location and offset in the Y direction by 0.4 units from the current Y location. If the current location has X = 0.7, Y = 0.7 at the outset, the center is at X = 1.0, Y = 1.1. If the starting value of Z is 0.9, this is a circular arc; otherwise, it's a helical arc. The radius of this arc would be 0.5.

In the center format, the radius of the arc is not specified, but it may be found easily as the distance from the center of the circle to either the current point or the end point of the arc.

```
(Sample Program G02EX3:)  
(Workpiece Size: X4, Y3, Z1)  
(Tool: Tool #2, 1/4" Slot Drill)  
(Tool Start Position: X0, Y0, Z1)  
N2 G90 G80 G40 G54 G20 G17 G94 G64 (SAFETY BLOCK)  
N5 G90 G20
```

```
N10 M06 T2 G43 H2
N15 M03 S1200
N20 G00 X1 Y1
N25 Z0.1
N30 G01 Z-0.1 F5
N35 G02 X2 Y2 I1 J0 F20 (ARC FEED CW, RADIUS I1,J0
AT 20 IPM)
N40 G01 X3.5
N45 G02 X3 Y0.5 R2 (ARC FEED CW, RADIUS 2)
N50 X1 Y1 R2 (ARC FEED CW, RADIUS 2)
N55 G00 Z0.1
N60 X2 Y1.5
N65 G01 Z-0.25
N70 G02 X2 Y1.5 I0.25 J-0.25 (FULL CIRCLE ARC FEED
MOVE CW)
N75 G00 Z1
N80 X0 Y0
N85 M05
N90 M30
```

9.2.5 Dwell (G04)

For a dwell, program: G04 P~

- P~ is the dwell time (measured in seconds)

Dwell keeps the axes unmoving for the period of time in seconds specified by the P number.



EXAMPLE

G04 P4.2 (to wait 4.2 seconds)

Troubleshooting

It's an error if:

- The P number is negative

9.2.6 Set Offsets (G10)

Use the controls on the Offsets tab to set offsets. You can program offsets with the G10 G-code command.

Read the following sections for reference:

Set Tool Table (G10 L1).....	193
Set Coordinate System (G10 L2).....	193
Set Tool Table (G10 L10).....	193
Set Tool Table (G10 L11).....	194
Set Coordinate System (G10 L20).....	194

Set Tool Table (G10 L1)

To define an entry in the tool table, program: G10 L1 P~ R~

- P~ is the tool number
- R~ is the radius of tool

G10 L1 sets the tool table for the P tool number to the values of the words. A valid G10 L1 rewrites and reloads the tool table.

Troubleshooting

It's an error if:

- Cutter Compensation is on
- The P number is unspecified
- The P number is not a valid tool number from the tool table
- The P number is 0

Set Coordinate System (G10 L2)

To define the origin of a work offset coordinate system, program: G10 L2 P~ <axes R~>

- P~ is the number of coordinate system to use (G54 = 1, G59.3 = 9)
- R~ is the rotation about the rotation about the Z-axis

The G10 L2 P~ command doesn't change from the current coordinate system to the one specified by P. Use G54 through G59.3 to select a coordinate system.

The coordinate system whose origin is set by a G10 command may be active or inactive at the time the G10 is executed. If it's currently active, the new coordinates take effect immediately. For example, if a G92 origin offset was in effect before G10 L2, it continues to be in effect after.

Optionally program R to indicate the rotation of the XY axis around the Z-axis. The direction of rotation is counterclockwise (viewed from the positive end of the Z-axis). When a rotation is in effect, jogging an axis only moves that axis in a positive or a negative direction — not along the rotated axis. To cancel a rotation for the active coordinate, program G10 L2 P0 R0.

Troubleshooting

It's an error if:

- The P number does not evaluate to an integer in the range 0-500
- An axis other than X or Z is programmed

Set Tool Table (G10 L10)

To change the tool table entry for tool P so that if the tool offset is reloaded with the machine in its current position and with the current G5x and G92 offsets active, program: G10 L10 P~ R~

9: PROGRAMMING

9.2 Programming G-Code

- $P\sim$ is the tool number
- $R\sim$ is the radius of tool

The current coordinates for the given axes become the given values. The axes that are not specified in the `G10 L10` command are not changed. This could be useful with a probe move (`G38`).

Troubleshooting

It's an error if:

- Cutter Compensation is on
- The P number is unspecified
- The P number is not a valid tool number from the tool table
- The P number is 0

Set Tool Table (G10 L11)

`G10 L11` is just like `G10 L10`, except that instead of setting the entry according to the current offsets, it's set so that the current coordinates would become the given value if the new tool offset is reloaded and the machine is placed in the `G59.3` coordinate system without any `G92` offset active. This allows you to set the `G59.3` coordinate system according to a fixed point on the machine, and then use that fixture to measure tools without regard to other currently active offsets.

Program: `G10 L11 P~ X~ Y~ Z~ R~`

- $P\sim$ is the tool number
- $R\sim$ is the radius of tool

Troubleshooting

It's an error if:

- Cutter Compensation is on
- The P number is unspecified
- The P number is not a valid tool number from the tool table
- The P number is 0

Set Coordinate System (G10 L20)

`G10 L20` is similar to `G10 L2`, except that instead of setting the offset/entry to the given value, it is set to a calculated value that makes the current coordinates become the given value.

Program: `G10 L20 P~ X~ Y~ Z~ A~`

- $P\sim$ is the number of coordinate system to use (`G54 = 1`, `G59.3 = 9`)
- $X\sim$ is the X-axis coordinate

- $Y\sim$ is the Y-axis coordinate
- $Z\sim$ is the Z-axis coordinate
- $A\sim$ is the A-axis coordinate

Troubleshooting

It's an error if:

- The P number does not evaluate to an integer in the range 0 to 9
- An axis other than X, Y, Z, or A is programmed

9.2.7 Plane Selection (G17, G18, G19)

To select the XY-plane as active, program: `G17`

To select the XZ-plane as active, program: `G18`

To select the YZ-plane as active, program: `G19`

The active plane determines how the tool path of an arc (`G02` or `G03`) or canned cycle (`G73`, `G81` through `G89`) is interpreted.

9.2.8 Length Units (G20 and G21)

To set length units to inches, program: `G20`

To set length units to millimeters, program: `G21`



Tip! Program either `G20` or `G21` near the beginning of a program, before any motion occurs. Avoid using either one anywhere else in the program. It's your responsibility to make sure that all numbers are appropriate for use with the current length units.

9.2.9 Return to Predefined Position (G28 and G28.1)

To make a rapid linear move from the current position to the absolute position of the values in parameters 5161-5166: `G28`

To make a rapid linear move to the `G28.1` position by first going to the intermediate position specified by the $X\sim$, $Y\sim$, and $Z\sim$ words, program: `G28 X~ Y~ Z~`



Note: Any axis not specified won't move.

To store the current location of the tool in the `G28.1` setting, program: `G28.1`

`G28` uses the values stored in parameters 5161, 5162, and 5163 as the X, Y, and Z final points to move to. The parameter values are absolute machine coordinates in the native machine units of inches.

To store the current absolute position into parameters 5161-5163, program: `G28.1`

If no positions are stored with `G28.1`, then all axes will go to the machine origin.

Troubleshooting

It's an error if:

- Cutter Compensation is turned on

9.2.10 Return to Predefined Position (G30 and G30.1)

G30 uses the values stored in parameters 5181 and 5183 as the X and Z final point to move to. The parameter values are absolute machine coordinates in the native machine units of inches.

To make a rapid traverse move from the current position to the absolute position of the values in parameters, program: `G30`

To make a rapid traverse move to the position specified by axes including any offsets, then make a rapid traverse move to the absolute position of the values in parameters 5181 and/or 5183, program: `G30 X~ Z~`



Note: Any axis not specified won't move.

To store the current absolute position into parameters 5181-5183, program: `G30.1`

Troubleshooting

It's an error if:

- Cutter Compensation is turned on

9.2.11 Automatically Measure Tool Lengths with an ETS (G37 and G37.1)

Use G37 and G37.1 with an Electronic Tool Setter (ETS) to enable automatic length measurement. For automated use, add a G37 command after an M6 tool change commands. If you're using the ETS with a mill, the input port varies depending on your machine:

- **M Series Mills** Plug the ETS into the Accessory Input 2 port. You can still use the Accessory Input 1 port for other probes and accessories.
- **Older PCNC Mills** Plug the ETS into the (single) accessory input port.

Move to G37 Position Over ETS (G37.1)

To move to the G37 position (over the ETS), program: `G37.1`

To set the G37 position:

1. Jog the machine over the center of the ETS.
2. From the **Probe** tab, on the **ETS Setup** tab, select **Set G37**

ETS Position.

The read-only DROs in the **ETS G37 Position Setup** group display the new position.

The G37 position is in G53 machine coordinate space. It defaults to (0, 0, 0), or the top left rear of machine travel (the same as the X-, Y-, and Z-axis reference position). G37.1 supports X and Y tool offsets. If there are X or Y tool offsets present in the tool table (manually applied through a G10 L1 command), they offset the spindle position. This enables G37 for tools mounted in an auxiliary spindle installed on the spindle column.



Note: If G10 L1 is used to change the X or Y offset of the currently loaded tool, you must then apply the new offsets with a G43 command.

G37.1 performs as follows:

1. A rapid upward move to the Z clear position (which is always G53 Z = 0.0).
2. A rapid move in X and Y to the X and Y ETS coordinates.
3. A rapid downward move in Z to the Z ETS coordinate.



Note: The Z word saves time by rapidly moving closer to the ETS before the slower probing begins. You must use caution if you set this lower than G53 Z = 0.0. If you don't, there's a risk that a long tool could collide with the ETS and damage it and the tool.

Move and Measure Tool Length (G37)

To move and measure the tool length, program: `G37 H~ P~`

- `H~` saves the measured tool length to the H tool table entry instead of the current tool number's entry. You could use this to track tool wear between the two tool table entries, for example.



Note: The newly measured tool length isn't applied, but it's stored in the tool table entry for tool number H.

9: PROGRAMMING

9.2 Programming G-Code

- $P\sim$ is positive or negative tolerance. It measures the tool length, but, instead of storing it in the tool table, compares it to the length in the tool table. If the difference exceeds the P tolerance, the G-code program stops. You could use this to detect broken or improperly inserted tools that are not fully seated in the spindle, for example.



Note: MX BT30 tool holders are designed to seat in the spindle taper, and should never touch the nose of the spindle.

G37 with no optional words moves to the G37 ETS position (through G37.1), probes the ETS, stores the new tool length in the tool table entry of the current tool, and applies the tool length offset.

G37 fails if the spindle nose hasn't been referenced to the ETS after a Z-axis reference. This sets a G53 coordinate at the ETS trigger point such that the measured tool length is the distance of the spindle nose to ETS reference. For more information, see the **ETS G37 Spindle Nose Reference** group on the **ETS Setup** tab.



Note: On MX mills, use the tip of the BT30 drive dog, not the spindle nose, to reference.

So that tool length measurements have consistent results, G37 uses the fine probe feed rate of 2.5 in./min for the final ETS touch. G37 uses the rough probe feed rate for the first ETS touch.

G37 performs as follows:

1. Issues a G37.1 move to the ETS location.
2. A downward rough probe feed rate move until the tool triggers the ETS.
3. An upward retract move of 0.100 in. to back off the triggered ETS.
4. A downward slow ETS probe feed rate move until the tool triggers the ETS.
5. An upward retract move of 0.100 in. to back off the triggered ETS.
6. An upward rapid move to the G37 ETS Z position.

9.2.12 Straight Probe (G38.x)

G38.2 probes toward the workpiece, stops on contact, and signals error if failure

G38.3 probes toward the workpiece and stops on contact

G38.4 probes away from the workpiece, stops on loss of contact, and signals error if failure

G38.5 probes away from the workpiece and stops on loss of contact

G38.6 moves away from the workpiece and ignores probe input

To perform a straight probe operation program: G31 $X\sim$ $Y\sim$

$Z\sim$ $A\sim$

Conventionally, the probe is tool #99. The rotational axis words are allowed, but it's better to omit them. If rotational axis words are used, the numbers must be the same as the current position numbers so that the rotational axes do not move. The tool in the spindle must be a probe.

In response to this command, the machine moves the controlled point (which should be at the end of the probe tip) in a straight line at the current feed rate toward the programmed point; if the probe trips, then the probe decelerates.

After successful probing, parameters 5061 to 5064 will be set to the coordinates of the location of the controlled point at the time the probe tripped (not where it stopped), or if it does not trip to the coordinates at the end of the move and a triplet giving X, Y, and Z at the trip is written to the triplet file.

Troubleshooting

It's an error if:

- The current point is less than 0.01 in. (0.254 mm) from the programmed point
- G38 is used in inverse time feed rate mode
- Any rotational axis is commanded to move
- No X-, Y- or Z-axis word is used
The linear axis words are optional, except that at least one of them must be used.
- Feed rate is zero
- The probe is already tripped

Use the Straight Probe Command

When you use the straight probe command, if the probe shank is kept nominally parallel to the Z-axis (i.e., any rotational axes are at zero) and the tool length offset for the probe is used, so

that the controlled point is at the end of the tip of the probe, you may be able to find:

- Without additional knowledge about the probe, the parallelism of a face of a part to the XY-plane
- If the probe tip radius is known approximately, the parallelism of a face of a part to the YZ or XZ-plane
- If the shank of the probe is known to be well-aligned with the Z-axis and the probe tip radius is known approximately, the center of a circular hole

If the shank of the probe is known to be well-aligned with the Z-axis and the probe tip radius is known precisely, you can use the straight probe command for things like finding the diameter of a circular hole.

```
Example code:
o<probe_pocket> sub
(probe to find center of circular or rectangular
pocket)
#<x_start> = #5420 (Current X Location)
#<y_start> = #5421 (Current Y Location)
#<x_max> = 1
#<x_min> = -1
#<y_max> = 1
#<y_min> = -1
#<feed_rate> = 30 (30 IPM)
F #<feed_rate>
G38.3 X #<x_max> (rough probe +X side of hole)
F [#<feed_rate>/30]
G38.5 X #<x_start> (finish probe)
#<x_plus>=#5061 (save results)
G00 X #<x_start> (return to start)
F #<feed_rate>
G38.3 X #<x_min> (probe -X side of hole)
F [#<feed_rate>/30]
G38.5 X #<x_start>
#<x_minus>=#5061 (save results)
G00 X #<x_start>
#<x_center> = [(#<x_plus>+#<x_minus>)/2]
G00 X #<x_center> (go to middle)
F #<feed_rate>
G38.3 Y #<y_max> (probe +Y side of hole)
F [#<feed_rate>/30]
G38.5 Y #<y_start>
#<y_plus>=#5062 (save results)
G00 Y #<y_start> (return to start)
F #<feed_rate>
G38.3 Y #<y_min> (probe -Y side of hole)
```

```
F [#<feed_rate>/30]
G38.5 Y #<y_start>
#<y_minus>=#5062 (save results)
G00 Y #<y_start>
#<y_center> = [(#<y_plus>+#<y_minus>)/2]
G00 Y #<y_center> (go to middle)
G10 L20 P1 X 0 Y 0 (set current location to zero)
F #<feed_rate> (restore original feed rate)
o<probe_pocket> endsub
M02
```

9.2.13 Cutter Compensation (G40, G41, G42)

To turn Cutter Compensation off, program: G40

It's okay to turn compensation off when it is already off.

It's an error if:

- A G02/G03 arc move is programmed next after a G40
- The linear move after turning compensation off is less than twice the tool tip radius

To program Cutter Compensation to the left of the programmed tool path (as viewed looking down on the machine), program: G41 D~

To program Cutter Compensation to the right of the programmed tool path (as viewed looking down on the machine), program: G42 D~

- D~ is the tool number associated with the diameter offset to be applied

The D word is optional — if there is no D word, the radius of the currently loaded tool is used. If no tool is loaded and no D word is given, a radius of 0 is used. If supplied, the D word is the tool number to use.

The lead in move must be at least as long as the tool radius.

The lead in move can be a rapid move.

It's an error if:

- The D number is not a valid tool number, or it's 0
- Cutter Compensation is commanded to turn on when it is already on

9.2.14 Dynamic Cutter Compensation (G41.1 and G42.1)

To program dynamic Cutter Compensation to the left of the programmed tool path, program: G41.1 D~

To program dynamic Cutter Compensation to the right of the programmed tool path, program: G42.1 D~

- D~ is the tip radius multiplied by two

9: PROGRAMMING

9.2 Programming G-Code

G41.1 and G42.1 function the same as G41 and G42, with the added scope of being able to ignore the tool table and to program the tool diameter.

Troubleshooting

It's an error if:

- Cutter Compensation is commanded to turn on when it is already on

9.2.15 Apply Tool Length Offset (G43)

To apply a tool length offset from a stored value in the tool table, program: G43 H~

- H~ is the tool number associated with the length offset to be applied.



Note: Generally speaking, the value of the H~ word should match the active tool number (T~ word).

It's okay to program using the same offset already in use, or to program without a tool length offset (if none is currently being used).

Troubleshooting

It's an error if:

- The H number is not an integer
- The H number is negative
- The H number is not a valid tool number

9.2.16 Engrave Sequential Serial Number (G47)

To engrave a serial number, either alone or added to the end of any text, program: Z~ R~ X~ Y~ P~ Q~ D~

- Z~ is the depth of cut of the engraving
- R~ is the retract height between character segments in the numbers
- X~ is, if present, the starting X position, or the left side of the serial number
If omitted, the current X position is assumed.
- Y~ is, if present, the starting Y position, or the bottom side of the serial number
If omitted, the current Y position is assumed.
- P~ is, if present, the X extent (width) in current units (inches or millimeters) of the engraved number
- Q~ is, if present, the Y extent (height) in current units (inches or millimeters) of the engraved number

- D~ is, if present, the requested number of decimals of the engraved number
If the requested D value exceeds the number of decimals in the serial number, the serial number will show leading zeros. If the requested D value is less than the number of decimals in the serial number, only the digits of the serial number will show.



EXAMPLE

A serial number of 10, where D = 4, engraves as 0010. A serial number of 9056, where D = 3, engraves as 9056.

Troubleshooting

It's an error if:

- Cutter Compensation is on
- The Z number is unspecified
- The R number is unspecified
- The Z number is greater than the R number
- The P number is too small (determined by the font used)
- The Q number is too small (determined by the font used)

9.2.17 Cancel Tool Length Compensation (G49)

To cancel tool length compensation, program: G49

9.2.18 Absolute Coordinates (G53)

For rapid linear motion to a point expressed in absolute coordinates, program: G01 G53 X~ Y~ Z~ (or use with G00 instead of G01)

All the axis words are optional, except that at least one must be used. The G00 or G01 is optional if it is in the current motion mode. G53 isn't modal, and must be programmed on each line on which it is intended to be active. This produces coordinated linear motion to the programmed point. If G01 is active, the speed of motion is the current feed rate (or slower if the machine won't go that fast). If G00 is active, the speed of motion is the current traverse rate (or slower if the machine won't go that fast).

Troubleshooting

It's an error if:

- G53 is used without G00 or G01 being active
- G53 is used while cutter radius compensation is on

9.2.19 Select Work Offset Coordinate System (G54 to G54.1 P500)

You can save up to 500 work offsets in PathPilot. The naming structure varies based on the offset number.

- To select work offset 1, program: G54 or G54.1 P1
- To select work offset 2, program: G55 or G54.1 P2
- To select work offset 3, program: G56 or G54.1 P3
- To select work offset 4, program: G57 or G54.1 P4
- To select work offset 5, program: G58 or G54.1 P5
- To select work offset 6, program: G59 or G54.1 P6
- To select work offset 7, program: G59.1 or G54.1 P7
- To select work offset 8, program: G59.2 or G54.1 P8
- To select work offset 9, program: G59.3 or G54.1 P9
- To select a work offset beyond the standard 9 (listed above), program: G54.1 P###, where P### is a parameter indicating the index of the work offset you want to use (work offset 10 through work offset 500).



EXAMPLE

To select the 124th work offset, program G54.1 P124.

For information, see "About Work Offsets" (page 180).

Troubleshooting

It's an error if:

- One of these G-codes is used while cutter radius compensation is on
- The X- and Z-axis work offset values are stored in parameters corresponding to the system in use (i.e., System 1 X=5221, Z=5223; System 2 X=5141, Z=5143; up to System 9 X= 5381, Z = 5383).

9.2.20 Set Exact Path Control Mode (G61)

To put the machining system into exact path mode, program: G61

9.2.21 Set Blended Path Control Mode (G64)

To attempt to maintain the defined feed velocity, program: G64 P~ Q~

- P~ is, if present, the maximum acceptable tool path deviation to round corners to maintain speed. If P is omitted then the speed is maintained however far from the programmed path the tool cuts.

- Q~ is, if present, the maximum deviation from collinearity that will collapse a series of linear G01 moves at the same feed rate into a single linear move.

It's okay to program for the mode that is already active.

9.2.22 Distance Mode (G90 and G91)

Interpretation of the operating system code can be in one of two distance modes: absolute or incremental.

To go into absolute distance mode, program: G90.

In absolute distance mode, axis numbers (X, Y, Z, A) usually represent positions in terms of the currently active coordinate system. Any exceptions to that rule are described explicitly in this section.

To go into incremental distance mode, program: G91.

In incremental distance mode, axis numbers (X, Y, Z, A) usually represent increments from the current values of the numbers. I and J numbers always represent increments, regardless of the distance mode setting. K numbers represent increments.

9.2.23 Arc Distance Mode (G90.1 and G91.1)

G90.1 – Absolute distance mode for I and K offsets. When G90.1 is in effect, I and K both must be specified with G02/G03 for the XZ plane or it is an error.

G91.1 – Incremental distance mode for I and K offsets.

G91.1 returns I and K to their default behavior.

9.2.24 Temporary Work Offsets (G92, G92.1, G92.2, and G92.3)



IMPORTANT! This is a legacy feature. Most modern programming methods don't use temporary work offsets.

To apply a temporary work offset, program: G92 X~ Y~ Z~ A~

- X~ is the X-axis coordinate
- Y~ is the Y-axis coordinate
- Z~ is the Z-axis coordinate
- A~ is the A-axis coordinate

G92 reassigns the current controlled point to the coordinates specified by the axis words (X~, Y~, Z~, and/or A~). No motion takes place.

The axis words are optional, except that at least one must be used. If an axis word is not used for a given axis, the coordinate on that axis of the current point is not changed.

9: PROGRAMMING

9.2 Programming G-Code

Incremental distance mode (G91) has no effect on the action of G92.

When G92 is executed, it is applied to the origins of all coordinate systems (G54 through G59.3).

EXAMPLE

If the current controlled point is at X = 4, and there is currently no G92 offset active, and then G92 X7 is programmed, this reassigns the current controlled point to X = 7 — effectively moving the origin of the active coordinate system -3 units in X. The origins of all inactive coordinate systems also move -3 units in X. This -3 is saved in parameter 5211.

G92 offsets may be already be in effect when the G92 is called. If this is the case, the offset is replaced with a new offset that makes the current point become the specified value.

It's an error if:

- All axis words are omitted

PathPilot stores the G92 offsets and reuses them on the next run of a program. To prevent this, you can program a G92.1 (to erase them), or program a G92.2 (to stop them being applied — they are still stored).

To reset axis offsets to zero and sets parameters 5211 - 5219 to zero, program: G92.1

To reset axis offsets to zero, program: G92.2

To set the axis offset to the values saved in parameters 5211 to 5219, program: G92.3

9.2.25 Feed Rate Mode (G93, G94, and G95)

To set the active feed rate mode to inverse time, program: G93

Inverse time is used to program simultaneous coordinated linear and coordinated rotary motion. In inverse time feed rate mode, an F word means the move should be completed in **[1/F number]** minutes.

EXAMPLE

If the F number is 2.0, the move should be completed in half a minute.

When the inverse time feed rate mode is active, an F word must appear on every line which has a G01, G02, or G03 motion, and an F word on a line that does not have G01, G02, or G03 is ignored. Being in inverse time feed rate mode does not affect G00 (rapid traverse) motions.

To set the active feed rate mode to units per minute mode, program: G94

In units per minute feed rate mode, an F word is interpreted to mean the controlled point should move at a certain number of inches per minute, or millimeters per minute, depending upon what length units are being used.

To set the active feed rate mode to units per revolution mode, program: G95

In units per revolution mode, an F word is interpreted to mean the controlled point should move a certain number of inches per revolution of the spindle, depending on what length units are being used. G95 is not suitable for threading, for threading use G33 or G76.

Troubleshooting

It's an error if:

- Inverse time feed rate mode is active and a line with G01, G02, or G03 (explicitly or implicitly) does not have an F word
- A new feed rate is not specified after switching to G94 or G95 canned cycle return level — G98 and G99

9.2.26 Spindle Control Mode (G96 and G97)

To set constant surface speed mode, program: G96 D~ S~

- D~ is the maximum spindle RPM.
This word is optional.
- S~ is the surface speed.



Note: If G20 is the active mode, the value is interpreted as feet per minute. If G21 is the active mode, the value is interpreted as meters per minute



EXAMPLE

G96 D2500 S250 (set constant surface speed with a maximum RPM of 2500, and a surface speed of 250).

When using G96 (the most common mode of machine operation), X0 in the current coordinate system (including offsets and tool lengths) must be the spindle axis.

To set RPM mode, program: G97

Troubleshooting

It's an error if:

- S is not specified with G96
- A feed move is specified in G96 mode while the spindle is not turning

9: PROGRAMMING
9.3 Programming Canned Cycles

9.3 PROGRAMMING CANNED CYCLES

Read the following sections for reference:

9.3.1 Canned Cycles Reference... 202
9.3.2 High Speed Peck Drill (G73)... 203
9.3.3 Cancel Canned Cycles (G80)... 203
9.3.4 Drilling Cycle (G81)... 203
9.3.5 Simple Drilling Cycle (G82)... 205
9.3.6 Peck Drilling Cycle (G83)... 205
9.3.7 Tapping Cycle (G84)... 205
9.3.8 Boring Cycle (G85)... 205
9.3.9 Boring Cycle (G86)... 206
9.3.10 Boring Cycle (G88)... 206
9.3.11 Boring Cycle (G89)... 206

9.3.1 Canned Cycles Reference

Supported Canned Cycles

Table with 2 columns: Canned Cycle, Description. Rows include G73 (High speed peck drilling cycle), G80 (Cancel active canned cycle), G81 (Simple drilling cycle), G82 (Simple drilling with dwell cycle), G83 (Peck drilling cycle), G84 (Tapping cycle), G85 (Boring cycle - feedrate out), G86 (Boring cycle - stop, rapid out), G88 (Boring cycle - stop, manual out), G89 (Boring cycle - dwell, feedrate out).

All canned cycles are performed with respect to the active plane. The descriptions we use assume the XY-plane has been selected. The behavior is always analogous if the YZ- or XZ-plane is selected.

- X~ is the X-axis coordinate
- Y~ is the Y-axis coordinate
- Z~ is the Z-axis coordinate
- A~ is the A-axis coordinate
- R~ is the retract position along the axis perpendicular to the currently selected plane (Z-axis for XY-plane, X-axis for YZ-plane, Y-axis for XZ-plane)

- L~ is the L number is optional and represents the number of repeats

All canned cycles use X, Y, Z, and R words. The R word sets the retract position; this is along the axis perpendicular to the currently selected plane (Z-axis for XY-plane, X-axis for YZ-plane, Y-axis for XZ-plane). Some canned cycles use additional arguments.

Rotational axis (A-axis) words are allowed in canned cycles, but it's better to omit them. If rotational axis words are used, the numbers must be the same as the current position numbers so that the rotational axes do not move.

The R number is always sticky — it keeps its value on subsequent blocks if they're not explicitly programmed to be different.

In absolute distance mode (G90), the X, Y, R, and Z numbers are absolute positions in the current coordinate system.

In incremental distance mode (G91), when the XY-plane is selected, X, Y, and R numbers are treated as increments to the current position and Z as an increment from the Z-axis position before the move involving Z takes place; when the YZ- or XZ-plane is selected, treatment of the axis words is analogous. Many canned cycles use the L word. The L word is optional and represents the number of repeats. L0 is not allowed. The L word is not sticky. The interpretation of the L word depends on the active distance mode:

- In incremental distance mode (G91), L > 1 in incremental mode means (with the XY-plane selected), that the X and Y positions are determined by adding the given X and Y numbers either to the current X and Y positions (on the first iteration) or to the X and Y positions at the end of the previous go-around (on the subsequent repetitions). The R and Z positions do not change during the repeats
- In absolute distance mode (G90), L > 1 means do the same cycle in the same place several times. Omitting the L word is equivalent to specifying L=1

The height of the retract move at the end of each repeat — called clear Z — is determined by the setting of the retract mode: either to the original Z position (if that is above the R position and the retract mode is G98) or otherwise to the R position.

Troubleshooting

It's an error if:

- X, Y, and Z words are all missing during a canned cycle
- A P number is required and a negative P number is used
- An L number is used that does not evaluate to a positive integer
- Rotational axis motion is used during a canned cycle
- Inverse time feed rate is active during a canned cycle
- Cutter radius compensation is active during a canned cycle

When the XY plane is active, the Z number is sticky and it's an error if:

- The Z number is missing and the same canned cycle was not already active
- The R number is less than the Z number

When the XZ plane is active, the Y number is sticky and it's an error if:

- The Y number is missing and the same canned cycle was not already active
- The R number is less than the Y number

When the YZ plane is active, the X number is sticky and it's an error if:

- The X number is missing and the same canned cycle was not already active
- The R number is less than the X number

At the very beginning of the execution of any of the canned cycles (with the XY-plane selected), if the current Z position is below the R position, the Z-axis will move in rapid motion to the R position. This happens only once, regardless of the value of L. In addition, at the beginning of the first cycle and each repeat, the following one or two moves are made:

- A straight traverse parallel to the XY-plane to the given XY-position
- A straight traverse of the Z-axis only to the R position, if it is not already at the R position

If the XZ- or YZ-plane is active, the preliminary and in-between motions are analogous.

9.3.2 High Speed Peck Drill (G73)

The G73 cycle is intended for deep drilling with chip breaking. The retracts in this cycle break the chip but do not totally retract the drill from the hole. It's suitable for tools with long flutes which clear the broken chips from the hole.

Program: G73 X~ Z~ R~ L~ Q~

- Q~ is the delta increment along the Z-axis

The G73 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate downward by delta or to the Z position (whichever is less deep).
- × **Step 3:** Rapid back incrementally in Z 0.010 in.
- × **Step 4:** Repeat Step 1 through 3 until the Z position is reached at Step 1.
- × **Step 5:** Rapid back down to the current hole bottom, backed off a bit.
- × **Step 6:** Retract the Z-axis at traverse rate to clear Z.

Troubleshooting

It's an error if:

- The Q number is negative or zero
- The R number is not specified

9.3.3 Cancel Canned Cycles (G80)

To cancels all canned cycles, program: G80

It's okay to program G80 if no canned cycles are in effect.

After a G80, the motion mode must be set with G00 (or any other motion mode G word). If motion mode is not set after G80, this error message appears: **"Cannot use axis values without a g code that uses them."**

9.3.4 Drilling Cycle (G81)

The G81 cycle is intended for drilling.

Program: G81 X~ Y~ Z~ A~ R~ L~

The G81 Cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- × **Step 3:** Retract the Z-axis at traverse rate to clear Z.

Examples

These examples demonstrate how the G81 canned cycle works in detail. Other canned cycles work in a similar manner.

9: PROGRAMMING

9.3 Programming Canned Cycles

EXAMPLE

The current position is (1, 2, 3), the XY-plane has been selected, and the following line of code is interpreted:

```
G90 G81 G98 X4 Y5 Z1.5 R2.8
```

This means that it's in absolute distance mode (G90), old Z retract mode (G98) and the G81 drilling cycle is performed once. The X number and X position are 4. The Y number and Y position are 5. The Z number and Z position are 1.5. The R number and clear Z are 2.8. The following moves take place:

1. G00 motion parallel to the XY-plane to (4,5,3)
2. G00 motion parallel to the Z-axis to (4,5,2.8)
3. G01 motion parallel to the Z-axis to (4,5,1.5)
4. G00 motion parallel to the Z-axis to (4,5,3)

EXAMPLE

The current position is (1, 2, 3), the XY-plane has been selected, the following line of code is interpreted: **G91**

```
G81 G98 X4 Y5 Z-0.6 R1.8 L3
```

This means that it's in incremental distance mode (G91), old Z retract mode, and the G81 drilling cycle is repeated three times. The X number is 4, the Y number is 5, the Z number is -0.6 and the R number is 1.8. The initial X position is 5 (=1+4), the initial Y position is 7 (=2+5), the clear Z position is 4.8 (=1.8+3) and the Z position is 4.2 (=4.8-0.6). Old Z is 3.0.

The first move is a traverse along the Z-axis to (1,2,4.8), since old Z < clear Z.

The first repeat consists of three moves:

1. G00 motion parallel to the XY-plane to (5,7,4.8)
2. G01 motion parallel to the Z-axis to (5,7, 4.2)
3. G00 motion parallel to the Z-axis to (5,7,4.8)

The second repeat consists of three moves. The X position is reset to 9 (=5+4) and the Y position to 12 (=7+5):

1. G00 motion parallel to the XY-plane to (9,12,4.8)
2. G01 motion parallel to the Z-axis to (9,12, 4.2)
3. G00 motion parallel to the Z-axis to (9,12,4.8)

The third repeat consists of three moves. The X position is reset to 13 (=9+4) and the Y position to 17 (=12+5):

1. G00 motion parallel to the XY-plane to (13,17,4.8)
2. G01 motion parallel to the Z-axis to (13,17, 4.2)
3. G00 motion parallel to the Z-axis to (13,17,4.8)

Example code using G81 cycle:

```
(Sample Program G81EX18:)  
(Workpiece Size: X4, Y3, Z1)  
(Tool: Tool #6, 3/4" HSS DRILL)  
(Tool Start Position: X0, Y0, Z1)  
N2 G90 G80 G40 G54 G20 G17 G94 G64 (Safety Block)  
N5 G90 G80 G20  
N10 M06 T6 G43 H6  
N15 M03 S1300  
N20 G00 X1 Y1  
N25 Z0.5  
N30 G81 Z-0.25 R0.125 F5 (Drill Cycle Invoked)  
N35 X2  
N40 X3  
N45 Y2
```

```
N50 X2
N55 X1
N60 G80 G00 Z1 (Cancel Canned Cycles)
N65 X0 Y0
N70 M05
N75 M30
```

9.3.5 Simple Drilling Cycle (G82)

The G82 cycle is intended for drilling.

Program: G82 X~ Y~ Z~ A~ R~ L~ P~

The G82 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- × **Step 3:** Dwell for the P number of seconds.
- × **Step 4:** Dwell for the P number of seconds.

9.3.6 Peck Drilling Cycle (G83)

The G83 cycle (often called peck drilling) is intended for deep drilling or milling with chip breaking. The retracts in this cycle clear the hole of chips and cut off any long stringers (which are common when drilling in aluminum).

Program: G83 X~ Y~ Z~ A~ R~ L~ Q~

- Q~ is a delta increment along the Z-axis

The G83 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate downward by delta or to the Z position, whichever is less deep.
- × **Step 3:** Rapid back out to the clear Z.
- × **Step 4:** Repeat Steps 1 through 3 until the Z position is reached at Step 1.
- × **Step 5:** Rapid back down to the current hole bottom, backed off a bit.
- × **Step 6:** Retract the Z-axis at traverse rate to clear Z.

Troubleshooting

It's an error if:

- The Q number is negative or zero

9.3.7 Tapping Cycle (G84)

The G84 cycle is intended for tapping. This cycle rotates the spindle clockwise to tap a pre-drilled hole; when the bottom of the hole is reached, the spindle rotates in the reverse direction and exits the hole.

Program: G84 X~ Y~ Z~ R~ P~ F~

- X~ is the position of the hole on the X-axis
- Y~ is the position of the hole on the Y-axis
- Z~ is the depth, tapping from the R-plane to the Z-depth
- R~ is the position of the retract plane (R-plane)
- P~ is the number of seconds to dwell
- F~ is the feed rate

The G84 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Start the spindle forward.
- × **Step 3:** Move the Z-axis at the programmed feed rate (F~) to the Z-depth.
- × **Step 4:** Reverse the spindle.
- × **Step 5:** Dwell for the P number of seconds.
- × **Step 6:** Retract the Z-axis at the programmed feed rate (F~) to the R-plane.

This cycle uses a P word, where P specifies the number of seconds to dwell. The P word is optional – if it is not included, PathPilot calculates a dwell for you (half of a second per 1000 RPM).

Spindle speed must be commanded before calling a G84 cycle. Feed rate override is ignored during a tapping cycle. Feedhold is ignored until the return operation is executed. After the tapping operation is completed, either a G98 or G99 command controls the return height — G99 returns the tool to the R-plane; G98 returns the tool to the initial height.



EXAMPLE

```
N40 T51 G43 H51 M6
N45 S400 M3
N50 G54
N55 M8
N65 G0 X0.5 Y-0.75
N70 G43 Z0.6 H51
N80 G0 Z0.2
N85 S400
N90 G98 G84 X0.5 Y-0.75 Z-0.605 R0.2 F20.
N95 X1.0 Y -1.25
N100 G80
N105 G0 Z0.6
```

9.3.8 Boring Cycle (G85)

The G85 cycle is intended for boring or reaming, but could be used for drilling or milling.

9: PROGRAMMING

9.3 Programming Canned Cycles

Program: G85 X~ Y~ Z~ A~ R~ L~

The G85 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- × **Step 3:** Retract the Z-axis at the current feed rate to clear Z.

9.3.9 Boring Cycle (G86)

The G86 cycle is intended for boring. This cycle uses a P number for the number of seconds to dwell.

Program: G86 X~ Y~ Z~ A~ R~ L~ P~

The G86 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- × **Step 3:** Dwell for the P number of seconds.
- × **Step 4:** Stop the spindle turning.
- × **Step 5:** Retract the Z-axis at traverse rate to clear Z.
- × **Step 6:** Restart the spindle in the direction it was going.
- × **Step 7:** Move the Z-axis only at the current feed rate to the Z position.

Troubleshooting

It's an error if:

- The spindle is not turning before this cycle is executed

9.3.10 Boring Cycle (G88)

The G88 cycle is intended for boring and uses a P word, where P specifies the number of seconds to dwell.

Program: G88 X~ Y~ Z~ A~ R~ L~ P~

The G88 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- × **Step 3:** Dwell for the P number of seconds.
- × **Step 4:** Stop the spindle turning.
- × **Step 5:** Stop the program so the operator can retract the spindle manually.
- × **Step 6:** Restart the spindle in the direction it was going.

9.3.11 Boring Cycle (G89)

The G89 cycle is intended for boring. This cycle uses a P number, where P specifies the number of seconds to dwell.

Program: G89 X~ Y~ Z~ A~ R~ L~ P~

The G89 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- × **Step 3:** Dwell for the P number of seconds.
- × **Step 4:** Retract the Z-axis at the current feed rate to clear Z.

9.4 PROGRAMMING M-CODE

Read the following sections for reference:

9.4.1 Supported M-Codes Reference.....	207
9.4.2 Program Stop and Program End (M00, M01, M02, and M30).....	207
9.4.3 Spindle Control (M03, M04, and M05).....	208
9.4.4 Tool Change (M06).....	208
9.4.5 Coolant Control (M07, M08, and M09).....	209
9.4.6 Override Control (M48 and M49).....	209
9.4.7 Feed Override Control (M50).....	209
9.4.8 Spindle Speed Override Control (M51).....	209
9.4.9 Set Current Tool Number (M61).....	209
9.4.10 Set Output State (M64 and M65).....	209
9.4.11 Wait on Input (M66).....	210
9.4.12 Switched Outlet Control (M264 and M265).....	210
9.4.13 USB Camera Control (M301, M302, M303).....	210

9.4.1 Supported M-Codes Reference

M-Code	Description
<u>M00</u>	Program stop
<u>M01</u>	Optional program stop
<u>M02</u>	Program end
<u>M03</u> , <u>M04</u>	Rotate spindle clockwise/counterclockwise
<u>M05</u>	Stop spindle rotation
<u>M07</u> , <u>M08</u>	Coolant on
<u>M09</u>	All coolant off
<u>M30</u>	Program end and rewind
<u>M48</u>	Enable speed and feed override
<u>M49</u>	Disable speed and feed override
<u>M64</u>	Activate output relays
<u>M65</u>	Deactivate output relays

M-Code	Description
<u>M66</u>	Wait on an input Note: <u>M64</u> through <u>M66</u> is only useful with a <u>USB M-Code I/O Interface Kit (PN 32616)</u>.
M98	Call subroutine
M99	Return from subroutine/repeat
<u>M264</u> , <u>M265</u>	Switched outlet control
<u>M301</u> , <u>M302</u> , <u>M303</u>	USB camera control

9.4.2 Program Stop and Program End (M00, M01, M02, and M30)

To stop a running program temporarily, regardless of the optional stop switch setting, program: M00

To stop a running program temporarily, but only if the optional stop switch is on, program: M01

It's okay to program M00 and M01 in MDI mode, but the effect probably won't be noticeable because normal behavior in MDI mode is to stop after each line of input.

If a program is stopped by an M00, M01, selecting Cycle Start restarts the program at the following line of the G-code program.

To end a program, program: M02 or M30.

M02 leaves the next line to be executed as the M02 line. M30 rewinds the G-code file. These commands can have the following effects:

- Axis offsets are set to zero (like G92 . 2) and origin offsets are set to the default (like G54)
- Selected plane is set to XY (like G17)
- Distance mode is set to absolute (like G90)
- Feed rate mode is set to units per minute mode (like G94)
- Feed and speed overrides are set to on (like M48)
- Cutter Compensation is turned off (like G40)
- The spindle is stopped (like M05)

9: PROGRAMMING

9.4 Programming M-Code

- The current motion mode is set to G01 (like G01)
- Coolant is turned off (like M09)

No more lines of code in the file are executed after the M02 or M30 command is executed. Selecting Cycle Start starts the program back at the beginning of the file.

Display Information and Capture Images During an M00 or M01 Break

Display Information with Images

If the comment occurs on a line with M00 or M01, and contains a file name with a .jpg or .png extension, PathPilot displays the image in the Tool Path display when the program reaches the M00 or M01 break.

To display an image during an M00 or M01 break:

1. Move an image file with a .jpg or .png extension to the PathPilot controller in one of the following locations:
 - In the same folder as the G-code program
 - In an images folder within the G-code program's folder
 - In an images folder within the home directory
2. Program an M00 or M01 break, and, using parentheses, type the full file name of the image (including its extension).



EXAMPLE

M01 (Op1_Setup.jpg) displays the image file on the Tool Path display.

3. The image file displays on the Tool Path display.

Display Information with Text

To display a message on the Tool Path display:

1. Program an M00 or M01 break, and, using parentheses, type a message that you'd like to display on the screen.



EXAMPLE

M01 (Check coolant nozzles are pointed correctly) displays *Check coolant nozzles are pointed correctly* across the bottom of the Tool Path display.

2. The message displays on the Tool Path display.

Capture Images with a USB Camera

In addition to displaying information like pictures or messages during an M01 break, you can also use a USB camera (if installed) to take a picture.

To use M01 to take pictures:

1. Add M01 (op1_setup.jpg) into your G-code program.
2. Run the G-code program.
3. When PathPilot executes the M01 it looks to see if the comment contains a file name.
 - If there isn't a file name: The comment is shown as instructional text across the tool path.
 - If there is a file name, but the file doesn't exist yet and the extension is .jpg, .png, or .jpeg: The USB cameras are initialized and shown in the tool path display.
4. Select the **Shutter** button to take the picture and create the op1_setup.jpg file.
In future runs of the G-code program, **op1_setup.jpg** will display to the operator for instructional purposes on the workpiece.

For more information, see "Use a USB Camera" (page 140).

9.4.3 Spindle Control (M03, M04, and M05)

To start the spindle turning clockwise at the currently programmed speed, program: M03

To start the spindle turning counterclockwise at the currently programmed speed, program: M04

The speed is programmed by the S word.

To stop the spindle from turning, program: M05

It's okay to use M03 or M04 if the spindle speed is set to 0; if this is done, the spindle won't start turning. If later the spindle speed is set above 0, the spindle starts turning. It is permitted to use M03 or M04 when the spindle is already turning, or to use M05 when the spindle is already stopped.

9.4.4 Tool Change (M06)

To execute a tool change sequence, program: M06

M06 behaves differently depending on whether or not the machine is equipped with an Automatic Tool Changer (ATC):

- If you have an ATC:
 - If the requested tool (T number) is assigned to the carousel, M06 initiates an automatic tool change.

- If the tool is not assigned to the carousel, you're prompted to manually change the tool and select Cycle Start to confirm the tool change. This resumes the program.
- If you don't have an ATC:
 - M06 commands the machine, stops the spindle, pauses program execution, and prompts operator to change tools by flashing Tool Change LED.
 - The program resumes after you select Cycle Start to confirm that the tool has been changed.

We recommend putting the T~, the M06, and the G43 H~ on one line (block) of code.

 **EXAMPLE**
N191 M06 T3 G43 H3

9.4.5 Coolant Control (M07, M08, and M09)

To turn coolant on, program: M07

To turn flood coolant on, program: M08

To turn all coolant off, program: M09

It's always okay to use any of these commands, regardless of what coolant is on or off.

9.4.6 Override Control (M48 and M49)

To enable the speed and feed override, program: M48

To disable both overrides, program: M49

It's okay to enable or disable the switches when they are already enabled or disabled.

9.4.7 Feed Override Control (M50)

To enable the feed rate override control, program: M50 P1

The P1 is optional.

To disable the feed rate control, program: M50 P0

When feed rate override control is disabled, the feed rate override slider has no influence, and all motion is executed at programmed feed rate (unless there is an adaptive feed rate override active).

9.4.8 Spindle Speed Override Control (M51)

To enable the spindle speed override control, program: M51 P1

The P1 is optional.

To disable the spindle speed override control, program: M51 P0

When spindle speed override control is disabled, the spindle speed override slider has no influence, and the spindle speed is equal to the value of the S word.

9.4.9 Set Current Tool Number (M61)

To change the current tool number while in MDI or manual mode, program: M61 Q~

- Q~ is the tool number

Troubleshooting

It's an error if:

- Q~ is not 0 or greater

9.4.10 Set Output State (M64 and M65)

 **Note:** These commands are only useful when the machine is equipped with the USB M-Code I/O Interface Kit.

There are four output relays available on the USB I/O module.

To activate output relays (contact close), program: M64

To deactivate output relays (contact open), program: M65

There are four contacts, numbered from 0 to 3. The contact is specified by the P word.

 **EXAMPLE**

- Activating the first relay: M64 P0
- Activating the second relay: M64 P1

The outputs are deactivated using M65 with the P word specifying the relay.

 **EXAMPLE**

- Deactivating the second relay: M65 P1
- Deactivating the fourth relay: M65 P3

There is only one P word and one relay per line. Each relay command must be done on an individual line.

The following is legal:

```
M64 P0
M64 P2
M64 P3
```

The following is not legal:

```
M64 P023
M64 P0 P2 P3
```

9: PROGRAMMING

9.4 Programming M-Code

9.4.11 Wait on Input (M66)



Note: This command is only useful when the machine is equipped with the USB M-Code I/O Interface Kit.

There are four digital inputs available on the USB I/O module.

M66 P- | E- <L->

- P- is the digital input number from 0 to 3.
- L- is the wait mode type:
 - Mode 0: IMMEDIATE – no waiting, returns immediately. The value of the input at that time is stored in parameter #5399.
 - Mode 1: RISE – waits for the selected input to perform a rise event.
 - Mode 2: FALL – waits for the selected input to perform a fall event.
 - Mode 3: HIGH – waits for the selected input to go to the HIGH state.
 - Mode 4: LOW – waits for the selected input to go to the LOW state.
- Q- is the timeout in seconds for waiting

The Q value is ignored if the L word is zero (IMMEDIATE). A Q value of zero is an error if the L word is non-zero.

9.4.12 Switched Outlet Control (M264 and M265)

To turn the 220 Vac switched accessory outlet on, program:

M264

To turn the 220 Vac switched accessory outlet off, program:

M265

9.4.13 USB Camera Control (M301, M302, M303)

PathPilot supports three new M-codes to control cameras within G-code programs: M301, M302, and M303. Example use cases:

- Record only across each M01 stop where the operator needs to flip a workpiece or change a tool.
- Create short videos that focus on unique aspects of the program to reduce later video editing.
- Record USB IO integration operations with robots or other devices (pneumatic vises, etc.).
- Monitor progress on a workpiece by including M303 throughout the program.

To begin a video recording by an attached camera, program: M301

To stop a video recording by an attached camera, program:

M302

To take a picture with an attached camera, program: M303

For more information, see "Use a USB Camera" (page 140).

9.5 PROGRAMMING INPUT CODES

Read the following sections for reference:

9.5.1 Feed Rate (F).....	211
9.5.2 Spindle Speed (S).....	211
9.5.3 Change Tool Number (T).....	211

9.5.1 Feed Rate (F)

To set the feed rate, program: `F~`

Depending on the setting of the feed mode toggle, the rate may be in units-per-minute or units-per-rev of the spindle. The units are those defined by the G20/G21 mode. The feed rate may sometimes be overridden.

9.5.2 Spindle Speed (S)

To set the speed in revolutions per minute (rpm) of the spindle, program: `S~`

The spindle turns at the commanded speed when it has been programmed to start turning. It's okay to program an S word whether the spindle is turning or not. If the speed override switch is enabled and not set at 100 percent, the speed is different from what is programmed. It's okay to program S0, but the spindle does turn if that is done.

Troubleshooting

It's an error if:

- The S number is negative

9.5.3 Change Tool Number (T)

It's your responsibility to make sure that the machine is in a safe place for changing tools (for example, by using G30). This allows optimization of motion which can save time. You can provide a pause for manual intervention with M00 or M01 before the tool change.

Troubleshooting

It's an error if:

- A negative T number is used
- A T number larger than 1000 is used

9: PROGRAMMING
9.6 Advanced Programming

9.6 ADVANCED PROGRAMMING

Parameter and expression programming language features are not used in common G-code application (hand coding), G-code created by PathPilot conversational programming, or the majority of third-party CAM-programming systems. There are significant differences between controls in the way parameters work. Do not assume that code from another control works in the same way with the operating system. We don't recommend writing parametric G-code — it's difficult to debug, and difficult for another operator to understand. Modern CAM virtually eliminates the need for it. Read the following sections for reference:

9.6.1 Parameters. 212
9.6.2 Expressions. 214
9.6.3 Subroutines. 215

9.6.1 Parameters

Read the following sections for reference:

Parameters Reference. 212
Numbered Parameters Reference. 213
Subroutine Parameters Reference. 213
Named Parameters Reference. 213

Parameters Reference

The RS274/NGC language supports parameters. Parameters are analogous to variables in other programming languages. PathPilot maintains an array of 10,320 numerical parameters. Many of them have specific uses. The parameters that are associated with fixtures are persistent over time. Other parameters are undefined when the operating system is loaded. The parameters are preserved when the interpreter is reset. Parameters 1 to 1000 can be used by the code of part-programs. There are several types of parameters of different purpose and appearance. The only value type supported by parameters is floating-point; there are no string, Boolean or integer types in G-code like in other programming languages. However, logic expressions can be formulated with Boolean operators (AND, OR, XOR, and the comparison operators EQ, NE, GT, GE ,LT, LE), and the MOD, ROUND, FUP and FIX operators support integer arithmetic.

Parameter Syntax

There are three types of parameters, numbered, named local, and named global. The type of the parameter is defined by its syntax:

- Numbered - #4711
• Named local - #<localvalue>
• Named global - #<_globalvalue>

Parameter Scope

The scope of a parameter is either global or local within a subroutine. The scope of each parameter is inferred from its syntax. Subroutine parameters and named local parameters have local scope. Named global parameters and all numbered parameters starting from #31 are global in scope. RS274/NGC uses lexical scoping. In a subroutine, only the local parameters defined therein and any global parameters are visible. The local parameters of a calling procedure are not visible in a called procedure.

Behavior of Uninitialized Parameters

Uninitialized global parameters and unused subroutine parameters return the value zero when used in an expression. Uninitialized named parameters signal an error when used in an expression.

Parameter Mode

The mode of a parameter can either be read/write or read-only. Read/write parameters may be assigned values within an assignment statement. Read-only parameters cannot be assigned values. They may appear in expressions, but not on the left-hand side of an assignment statement.

Persistence and Volatility

Parameters can either be persistent or volatile. When the operating system is powered off, volatile parameters lose their values and are reset to zero. The values of persistent parameters are saved in a disc file and restored to their previous values when the operating system is powered on again. All parameters except numbered parameters in the current persistent range (5163 to 5390) are volatile.

Intended Use

Numbered parameters in the range #31-#5000, named global, and local parameters are available for general-purpose storage of floating-point values, like intermediate results, flags, etc., throughout program execution. They are read/write (can be

assigned a value). Subroutine parameters, numbered parameters #1-#30, and system parameters are read-only and not available for general use. Subroutine parameters are used to hold the actual parameters passed to a subroutine. Numbered parameters in the range of #1-#30 are used to access offsets of coordinate systems. System parameters are used to determine the current running version and are read-only.

Numbered Parameters Reference

A numbered parameter is recognized by the pound symbol (#) followed by an integer between 1 and 5399. The parameter is referred to by this integer, and its value is whatever number is stored in the parameter. A value is stored in a parameter with the (=) operator.

Example: `#3 = 15` (set parameter 3 to 15)

A parameter setting does not take effect until after all parameter values on the same line have been found. For example, if parameter 3 has been previously set to 15 and the line: `#3=6 G01 X#3` is interpreted, a straight move to a point where X = 15 occurs before the value of parameter 3 is set to 6.

The # symbol takes precedence over other operations. For example, `#1+2` means the number found by adding 2 to the value of parameter 1, not the value found in parameter 3. Of course, `# [1+2]` does mean the value found in parameter 3. The # character may be repeated; for example `##2` means the value of parameter whose index is the (integer) value of parameter 2. PathPilot maintains a number of read-only parameters. Only parameters for the relevant axes are maintained: (X Y Z A) for mill and (X Z) for lathe. The remaining parameters for unused axes are undefined.

Read-Only Parameters

- 1-30: Subroutine local parameters of call arguments. These parameters are local to the subroutine. For further information, see Programming with Subroutines later in this chapter
- 31-5000: G-code operator parameters. These parameters are global in G-code file
- 5061-5070: Result of G38.2 probe (X Y Z A B C U V W)
- 5161-5169: G28 home for (X Y Z A B C U V W)
- 5181-5189: G30 home for (X Y Z A B C U V W)
- 5210: 1 if G92 offsets are active, 0 if not
- 5211-5219: G92 offset (X Y Z A B C U V W)

- 5220: Current coordinate system number 1-9 for G54 - G59.3
- 5221-5230: Coordinate System 1, G54 (X Y Z A B C U V W R) – R denotes XY rotation angle around Z-axis
- 5241-5250: Coordinate System 2, G55 (X Y Z A B C U V W R)
- 5261-5270: Coordinate System 3, G56 (X Y Z A B C U V W R)
- 5281-5290: Coordinate System 4, G57 (X Y Z A B C U V W R)
- 5301-5310: Coordinate System 5, G58 (X Y Z A B C U V W R)
- 5321-5330: Coordinate System 6, G59 (X Y Z A B C U V W R)
- 5341-5350: Coordinate System 7, G59.1 (X Y Z A B C U V W R)
- 5361-5370: Coordinate System 8, G59.2 (X Y Z A B C U V W R)
- 5381-5390: Coordinate System 9, G59.3 (X Y Z A B C U V W R)
- 5399: Result of M66 – check or wait for input
- 5400: Current tool number
- 5401-5409: Tool offset (X Y Z A B C U V W)
- 5410: Current tool diameter
- 5411: Current tool front angle
- 5412: Current tool back angle
- 5420-5428: Current position including offsets in current program units (X Y Z A B C U V W)

Subroutine Parameters Reference

Subroutine parameters are specifically reserved for call arguments. By definition, these are parameters #1-#30 and are local to the subroutine.

Named Parameters Reference

Named parameters work like numbered parameters, but are easier to read and remember. All parameter names are converted to lowercase and have spaces and tabs removed. Named parameters must be enclosed with < > marks. `#<named parameter here>` is a local named parameter. By default, a named parameter is local to the scope in which it is assigned.

You can't access a local parameter outside of its subroutine. This is so two subroutines can use the same parameter names

9: PROGRAMMING
9.6 Advanced Programming

without fear of one subroutine overwriting the values in another.
#<_global named parameter here> (i.e., name starting with an underscore) is a global named parameter.
They are accessible from within called subroutines and may set values within subroutines that are accessible to the caller.
As far as scope is concerned, they act just like regular numeric parameters. They are not made persistent by storage in a file.
The global parameters _a, _b, _c, ... _z are reserved for special use. Do not use these parameters.

EXAMPLES

- #<_endmill_dia> = 0.049 is a declaration of named global variable.
- #<_endmill_rad> = [#<_endmill_dia>/2.0] is a reference to previously declared global variable.
- o100 call [0.0] [0.0] [#<_inside_cutout>-#<_endmill_dia>] [#<_Zcut>] [#<_feedrate>] is mixed literal and named parameters.

9.6.2 Expressions

An expression is a set of characters starting with a left bracket ([) and ending with a right bracket (]). Located between the brackets are numbers, parameter values, binary operators, functions, and other expressions. An expression is evaluated to produce a number. An example of an expression is:
[1 + acos[0] - [#3 ** [4.0/2]]]
All expressions on a line are evaluated when the line is read and before anything on the line is executed.
Read the following sections for reference:

Binary Operators Reference214
Functions Reference. 214

Binary Operators Reference

Binary operators only appear inside expressions. There are three types of binary operators: mathematical, logical, and relational.

There are four basic mathematical operations: addition (+), subtraction (-), multiplication (*), and division (/). In addition, the modulus operation (MOD) finds the remainder after division of one number by another number. The power operation (**) of raising the number on the left of the operation to the power on the right. There are three logical operations: non-exclusive or (OR), exclusive or (XOR), and logical and (AND).
The relational operators are equality (EQ), inequality (NE), strictly greater than (GT), greater than or equal to (GE), strictly less than (LT), and less than or equal to (LE).

Binary operators are divided into several groups according to their precedence as follows, from highest to lowest:

- 1. **
- 2. * / MOD
- 3. + -
- 4. EQ NE GT GE LT LE
- 5. AND OR XOR

If operations in different precedence groups are strung together, operations with a higher precedence are performed before operations with a lower precedence. If an expression contains more than one operation with the same precedence, the operation on the left is performed first.

EXAMPLE

[2.0 / 3 * 1.5 - 5.5 / 11.0] is equivalent to
[[[2.0 / 3] * 1.5] - [5.5 / 11.0]]
which is equivalent to [1.0 - 0.5]
which is
0.5

The logical operations and modulus are to be performed on any real numbers, not just on integers. The number zero is equivalent to logical false, and any non-zero number is equivalent to logical true.

Functions Reference

- The available functions are:
- ATAN[Y] / [X]: Four quadrant inverse tangent
 - ABS[arg]: Absolute value
 - ACOS[arg]: Inverse cosine
 - ASIN[arg]: Inverse sine
 - COS[arg]: Cosine
 - EXP[arg]: e raised to the given power (ex)

- `FIX[arg]`: Round down to integer
- `FUP[arg]`: Round up to integer
- `ROUND[arg]`: Round to nearest integer
- `LN[arg]`: Base-e logarithm
- `SIN[arg]`: Sine
- `SQRT[arg]`: Square root
- `TAN[arg]`: Tangent
- `EXISTS[arg]`: Check named parameter

9.6.3 Subroutines

Subroutines are subprograms that are called from inside another program.

Read the following sections for reference:

Subroutines Reference	215
Conditional Subroutines Reference	216
Repeating Subroutines Reference	216
Looping Subroutines Reference	216

Subroutines Reference

Subroutines are identified in a program by a unique subroutine label. The subroutine label is the letter `O` followed by an integer (with no sign) between 0 and 99999 written with no more than five digits (000009 is not permitted, for example) or a string of characters surrounded by `<>` symbols.

Examples of valid subroutine labels:

- `O123`
- `O99999`
- `O<my test code>`

Subroutine labels may be used in any order, but they must be unique in a program. Each subroutine label must be followed by a subroutine keyword. The subroutine keyword defines the action associated with the subroutine label.

Valid subroutine keywords and their meanings are:

- `Sub`: Begin subroutine definition
- `Endsub`: End of subroutine definition
- `Call`: Call the subroutine
- `Do/while/endwhile`: Execute the subroutine while a condition is true
- `Repeat/endrepeat`: Execute the subroutine while a condition is true
- `If/elseif/else/endif`: Conditionally execute the subroutine
- `Break`: Break out of a while or if/elseif statement

- `Continue`: Skip remaining code and restart at top of while or repeat loop
- `Return`: Return a value

The `sub` and `endsub` keywords are used to define the beginning and end a subroutine. All lines of code between the `sub` and `endsub` keywords are considered to be part of the subroutine.

Example of `sub`, `endsub`, `call`:

```
O100 sub
G53 G00 X0 Y0 Z0 (rapid move to machine home)
O100 endsub
...
O100 call (call the subroutine here)
M02
```

Subroutines can either be defined in the program file or in a separate file. If the subroutine is defined in the same file as the main program that calls the subroutine, it must be defined before the call statement.

For example, this is valid:

```
O100 sub
G53 G00 X0 Y0 Z0 (rapid move to machine home)
O100 endsub
...
O100 call (call the subroutine here)
M02
```

But this is not:

```
O100 call (call the subroutine here)
M02
O100 sub
G53 G00 X0 Y0 Z0 (rapid move to machine home)
O100 endsub
...
```

A subroutine can be a separate file as long as:

- The file is named the same as your call.
- The file includes a `sub` and `endsub` in the file.
- The file is in the directory `/subroutines`.
- The file name only includes lowercase letters, numbers, dashes, and underscores.
- The file only contains a single subroutine definition.
- The file ends with the extension `.nc`.

9: PROGRAMMING

9.6 Advanced Programming

Note: File names are lowercase letters only.

 `o<MyFile>` is converted to `o<myfile>` by the interpreter.

To execute a subroutine in a program, it must be called. To call a subroutine, program `o~ call` where ~ is the subroutine name. The subroutine name may be either a named file, a numbered file, or an expression that evaluates to a valid subroutine label.

- Expression example: `o[#101+2] call`
- Named file example: `o<myfile> call`
- Numbered file example: `o123 call`

`o~ call` takes up to 30 optional arguments, which are passed to the subroutine as #1, #2, . . . , #N. Unused parameters from #N+1 to #30 have the same value as in the calling context.

Parameters #1-#30 are local to the subroutine. On return from the subroutine, the values of parameters #1 through #30 (regardless of the number of arguments) are restored to the values they had before the call.

The following calls a subroutine with three arguments: `o200 call [1] [2] [3]`

Because 1 2 3 is parsed as the number 123, the parameters must be enclosed in square brackets.

Subroutine bodies may be nested.

- Nested subroutines may only be called after they are defined.
- They may be called from other functions, and may call themselves recursively if it makes sense to do so.
- The maximum subroutine nesting level is 10.

Subroutines do not have return values, but they may change the value of parameters above #30 and those changes are visible to the calling G-code. Subroutines may also change the value of global named parameters.

Conditional Subroutines Reference

Subroutines can be conditionally executed using the if/endif or the if/else/elseif/endif keyword constructs.

if/endif

The if/endif conditional will execute a block of code following the if keyword only when the if argument evaluates to true.

```
If/endif example:
o100 sub
```

```
(notice that the if-endif block uses a different
number)
o110 if [#2 GT 5]
(some code here)
o110 endif
(some more code here)
o100 endsub
```

if/elseif/else/endif

The if/elseif/else/endif conditional will execute the block of code following the if keyword when its argument evaluates to true. If the argument evaluates to false, then the code following each elseif is executed as long as the associated elseif argument evaluates to true. If no elseif keywords are present, or if all elseif arguments evaluate to false, then the code following the else keyword is executed.

```
If/elseif/endif example:
o102 if [#2 GT 5] (if parameter #2 is greater than
5 set F100)
F100
o102 elseif [#2 LT 2] (else if parameter #2 is
less than 2 set F200)
F200
o102 else (else if parameter #2 is 2 through 5 set
F150)
F150
o102 endif
```

Repeating Subroutines Reference

Subroutines can be repeated a finite number of times using the repeat/endrepeat keyword.

```
Repeat example:
(Mill 5 diagonal shapes)
G91 (Incremental mode)
o103 repeat [5]
... (insert milling code here)
G00 X1 Y1 (diagonal move to next position)
o103 endrepeat
G90 (Absolute mode)
```

Looping Subroutines Reference

Subroutines can be looped using the do/while or while/endwhile keyword constructs.

do/while

The do/while loop executes a block of code once and continues to execute the code block until the while argument evaluates to true.

```
Do/while loop example:
#1 = 0 (assign parameter #1 the value of 0)
o100 do
  (debug, parameter 1 = #1)
o110 if [#1 EQ 2]
  #1 = 3 (assign the value of 3 to parameter #1)
  (msg, #1 has been assigned the value of 3)
o100 continue (skip to start of loop)
o110 endif
  (some code here)
  #1 = [#1 + 1] (increment the test counter)
o100 while [#1 LT 3]
M02
```

while/endwhile

The while/endwhile repeats a set of statements an indefinite number of times, as long as the while argument evaluates to true.

```
While/endwhile example:
(draw a sawtooth shape)
G00 X1 Y0 (move to start position)
#1 = 1 (assign parameter #1 the value of 0)
F25 (set a feed rate)
o101 while [#1 LT 10]
G01 X0
G01 Y[#1/10] X1
#1 = [#1+1] (increment the test counter)
o101 endwhile
M02 (end program)
```

The following statements cause an error message and abort the interpreter:

- A label on break or continue which does not point to a matching while or do
- A label on endrepeat or endwhile no referring to a corresponding while or repeat
- A return or endsub not within a sub definition
- A label on repeat which is defined elsewhere
- A label on while which is defined elsewhere and not referring to a do
- A label on if defined elsewhere
- A undefined label on else or elseif
- A label on else, elseif or endif not pointing to a matching if



MACHINE MAINTENANCE

IN THIS SECTION, YOU'LL LEARN:

- About the required maintenance procedures that you must do so that this machine operates as designed.



Before operating the machine in any way, you must read and understand this section.

CONTENTS

10.1 Maintenance Safety	220
10.2 Maintenance Schedules	221
10.3 Regular Maintenance	222

10: MACHINE MAINTENANCE

10.1 Maintenance Safety

10.1 MAINTENANCE SAFETY

Read and understand the following safety messages before beginning any maintenance procedures.

10.1.1 All Maintenance Procedures

- ✓ Understand that the machine is automatically controlled and can start at any time.
- ✓ Power off the machine and disconnect the pneumatic supply before doing any maintenance procedures.
- ✓ When appropriate, lockout/tagout the Main Disconnect switch and the pneumatic supply line before doing any maintenance procedures.
- ✓ Wear safety eye protection rated for ANSI Z87+.

10.1.2 Swarf Maintenance Procedures

- ✓ Wear work gloves.

10.1.3 Coolant Maintenance Procedures

- ✓ Wear rubber gloves.

10.2 MAINTENANCE SCHEDULES

To keep your machine running as smoothly as possible, you must regularly do the following maintenance procedures.



Note: Before you begin any maintenance procedures, read and understand "Maintenance Safety" (on the previous page).

If you disassemble any components, refer to the machine's reference drawings when you've completed the maintenance procedure. For information, see "Diagrams and Parts Lists" (page 225). For any additional support, we can help. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

10.2.1 Daily

- ☐ Clean the way covers of chips.
- ☐ Clean the chip baskets on the coolant tank.
- ☐ Examine the coolant level and condition.
- ☐ Examine the way oil level and refill as necessary.
- ☐ Retract the plunger on the manual oiler, hold it in the retracted position for two seconds, and then release it.



Note: The plunger should move slowly from the retracted position. If it doesn't, it could indicate a malfunctioning oiler.

- ☐ Verify that the regulator has at least 90 psi compressed air (for pneumatic accessories installed, like the Power Drawbar).
- ☐ Verify that the door switches are properly functioning.

10.2.2 Weekly

- ☐ Clean all exterior surfaces with a clean rag.
- ☐ Verify that the machine's lubrication points (sliding surfaces and ball screw nuts) are receiving way oil.
- ☐ Examine the enclosure and other guards for damage.
- ☐ Examine the drawbar for wear.
- ☐ Remove vises, fixture plates, rotary tables, and other accessories, and then examine them for rust. If needed, reapply rust inhibitor before reinstalling

workholding and accessories.

- ☐ Check coolant concentration.

10.2.3 Monthly

- ☐ Clean the electrical cabinet vents of dust with a clean cloth or compressed air.
- ☐ Clean fine swarf from the coolant tank.
- ☐ Examine all axes' slideway surfaces and ball screws to determine if an oil film is present.
- ☐ Examine the air tool oil level in the FRL Filter-Regulator-Lubricator and refill as necessary.

10.2.4 Semi-Annually



Note: After the first 90 days of operation, complete the items on this list. After that, complete the items every six months.

- ☐ Examine the spindle belt for wear.
- ☐ Examine the way covers for wear.
- ☐ Examine the X-axis flex conduit for wear.

10.2.5 Annually

- ☐ Remove the way covers and examine them for wear. Clean any chips or oil underneath the way covers.
- ☐ Examine the windows and replace them if necessary.
- ☐ Check the machine's backlash.

10: MACHINE MAINTENANCE

10.3 Regular Maintenance

10.3 REGULAR MAINTENANCE

10.3.1 Clean the Way Covers.....	222
10.3.2 Clean the Coolant System.....	222
10.3.3 Examine the Drawbar.....	223
10.3.4 Examine the Enclosure Windows.....	223
10.3.5 Lubricate the Machine.....	223
10.3.6 Examine the Spindle Belt.....	224
10.3.7 Examine the Pull Stud Clamp.....	224
10.3.8 Prevent Rust.....	224

10.3.1 Clean the Way Covers

To extend the service life of the machine, you must make sure that the way covers are protecting the machine's slideways.

Regularly do the following:

- Examine the way covers for signs of wear or damage. If the way covers are damaged, you must replace them.
 - [Y-Axis Front Way Cover \(PN 31419\)](#)
 - [Y-axis Rear Way Cover \(PN 31437\)](#)
 - [Z-axis Way Cover \(PN 31433\)](#)
- Use a chip brush to clean the way covers of chips and other swarf.

10.3.2 Clean the Coolant System

To extend the service life of the coolant and the coolant pump, you must make sure that both are free of contaminants.

Regularly do the following:

- Use a chip brush to clean the machine, chip trays, and enclosure of chips and other swarf.
- Empty the chip strainer on the coolant tank.
- Measure the coolant concentration, pH, and volume, and then compare your findings to the material's safety data sheet (SDS).
 - **Coolant Level Too Low** Fill the coolant tank with fresh coolant, making sure that it is the appropriate concentration.
 - **Coolant pH Outside of Manufacturer's Recommended Coolant Limits** Adjust the pH according to the manufacturer's recommendation.



Note: You must only use coolant that is recommended for machining. See "Cutting Fluid Reference" (below).

- Examine the coolant pump's impeller for blockages.
- To remove tramp way oil from the coolant tank, use one of the following:
 - [Oil Skimmer Kit \(PN 39298\)](#)
 - [Floating Tramp Oil Collection Pillow \(PN 31925\)](#)

Periodically do the following:

- Remove the coolant tank covers and the chip strainer, and then clean the fine swarf from the coolant tank.
- If you're using a filter to prevent small particles from entering the coolant tank, replace it when it's saturated with chips, swarf, or tramp oil.
- Examine the coolant for contamination, and determine if the coolant's oil-water emulsion has broken.
- Drain and thoroughly clean the coolant tank, and then replace with fresh coolant.

NOTICE! Hazardous Waste: Only dispose of coolant as advised by local environmental protection authorities. You must not dispose of coolant in a septic system or a sewer.

About Cutting Fluid

Clean and well maintained coolant has increased performance, prevents rust, and smells better than contaminated coolant.

Coolant becomes contaminated when:

- Swarf accumulates in the chip pans, the chip strainer, or the coolant tank.
- Tramp oil isn't regularly removed from the coolant tank.
- The concentration or pH aren't maintained to the manufacture's specifications.

Cutting Fluid Reference

Using flood coolant provides the following benefits:

- Cools the cutting zone
- Flushes away swarf
- Lubricates the cutting tool
- Provides some degree of rust inhibition

You must only use flood coolant that is recommended for CNC machining applications, like:

- Soluble oils
- Semi-synthetic coolants
- Synthetic coolants

You must never use:

- Coolant without rust inhibitors
- Flammable coolants such as alcohols, diesel fuel, or kerosene



WARNING! Fire Hazard: The machine and its enclosure are not designed to contain fire or explosions. Only use materials and coolants that are intended for the specific machining operation. Never use flammable or explosive items.

- Straight cutting oil
- Water

If you use a coolant concentrate, you must mix it with water to the dilution ratio recommended by the coolant manufacturer. Use an optical refractometer to measure coolant concentration.

10.3.3 Examine the Drawbar

To extend the service life of the drawbar, you must make sure that the drawbar isn't damaged, and that it's properly lubricated.

Regularly do the following:

- Examine the drawbar for signs of wear or damage.

For the Power Drawbar, regularly do the following:

- Use Anti-Seize to lubricate the Power Drawbar disc springs (the Belleville washers) and clamping mechanism.
- Examine the BT30 drawbar stroke and adjust if necessary.

10.3.4 Examine the Enclosure Windows

Regularly examine the enclosure windows, and all other guarding, for signs of wear or damage.

When required, replace the windows with the following parts:

- Window, 770, Side (PN 37625)
- Window, 770M, Left Door (PN 37623)
- Window, 770M, Right Door (PN 37624)

10.3.5 Lubricate the Machine

To keep the machine operating properly, and to extend the service life of the machine, you must verify that the slideway

surfaces and ball screws are receiving lubrication.

Regularly do the following:

- Clean the oil reservoir's cover and all exposed surfaces surrounding the oil reservoir. Swarf or debris that enters the oil reservoir can plug the small, internal passages of the lubrication system.



Note: The strainer at the top of the oil reservoir isn't a filter, and can't remove all types of debris that may cause blockages.

- Examine all axes' slideway surfaces and ball screws to determine if an oil film is present. If there's not an oil film, examine the lubrication system for blockages, broken fittings, or pinched oil lines.
- Examine the amount of available oil and, if necessary, refill with new, high-quality ISO VG 68 grade Machine Oil (PN 31386).

About the Manual Oiler

The manual oiler operates with a plunger:

- **On the Pull Stroke** The oiler pulls machine oil from the oil reservoir.
- **On the Retract Stroke** The oiler pushes machine oil through the lubrication system.

The plunger is spring-loaded, and creates a light hydraulic pressure sufficient to distribute the oil through the machine. Do not push the plunger after you retract it.

When the machine is first powered on (and then after every four hours of operation), retract the oiler's plunger and hold it in the retracted position for two seconds. Then, release the oiler's plunger.



Note: The plunger should move slowly from the retracted position. If it doesn't, it could indicate a malfunctioning oiler.

About the Automatic Oiler

Lubrication System Reference

The machine's lubrication system distributes oil to the following 15 points:

10: MACHINE MAINTENANCE

10.3 Regular Maintenance

- 12 slideways bearing surfaces
 - Four on the X-axis
 - Four on the Y-axis
 - Four on the Z-axis
- Three ball screw nuts

10.3.6 Examine the Spindle Belt

To extend the service life of the spindle belt, you must regularly examine it for signs of damage or wear.

If the spindle belt is damaged, you must replace it with 770 Spindle Pulley Belt (PN 31435).

10.3.7 Examine the Pull Stud Clamp

To extend the service life of your spindle, you must regularly do the following:

- Examine the pull stud clamp for signs of wear or damage.
- Make sure the inside of the spindle taper is clean and dry.
- Use Anti-Seize (PN 31273) to lubricate the working surfaces of the pull stud clamp.
- Use a mild degreaser to clean the shank of all tool holders.

10.3.8 Prevent Rust

Take proper care to protect all exposed iron and steel surfaces on your machine. To reduce the possibility of rust, you must regularly do the following:

- Clean the machine, chip pans, and enclosure of chips and other swarf with a chip brush.
- Clean all exterior surfaces with a mild cleaner.
- Only use flood coolant that is recommended for machining (see "Cutting Fluid Reference" (page 222)).
- Periodically test the coolant concentration, and adjust (if necessary) to meet coolant manufacturer's recommended concentration.
- Put LPS 3® (or similar rust inhibitor) on the machine before installing any workholding or accessories.
- Only operate the machine in a temperature- and humidity-controlled environment. Extreme changes in temperature or humidity can create condensation on the machine.

- Put LPS 3® (or similar rust inhibitor) on all exposed, non-painted metal surfaces before leaving the machine unused.
- Remove all workholding and accessories, and then check for rust.
- If needed, reapply rust inhibitor before reinstalling workholding or accessories.

If you find rust on the machine table, go to "Remove Rust" (below).

Remove Rust

Use a fine machinist's stone to remove light surface rust on the machine table: use light, even pressure, and move the stone in a random motion to avoid changing the flatness of the machine table.

If you find a lot of rust, or if there is rust on the machine's slideways or ball screws, take photos of all rust-covered areas. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

DIAGRAMS AND PARTS LISTS

IN THIS SECTION, YOU'LL LEARN:

- About this machine's components.

NOTICE! Only use Tormach-approved parts when making replacements. If you don't replace parts with those listed in this section, you may void your warranty.

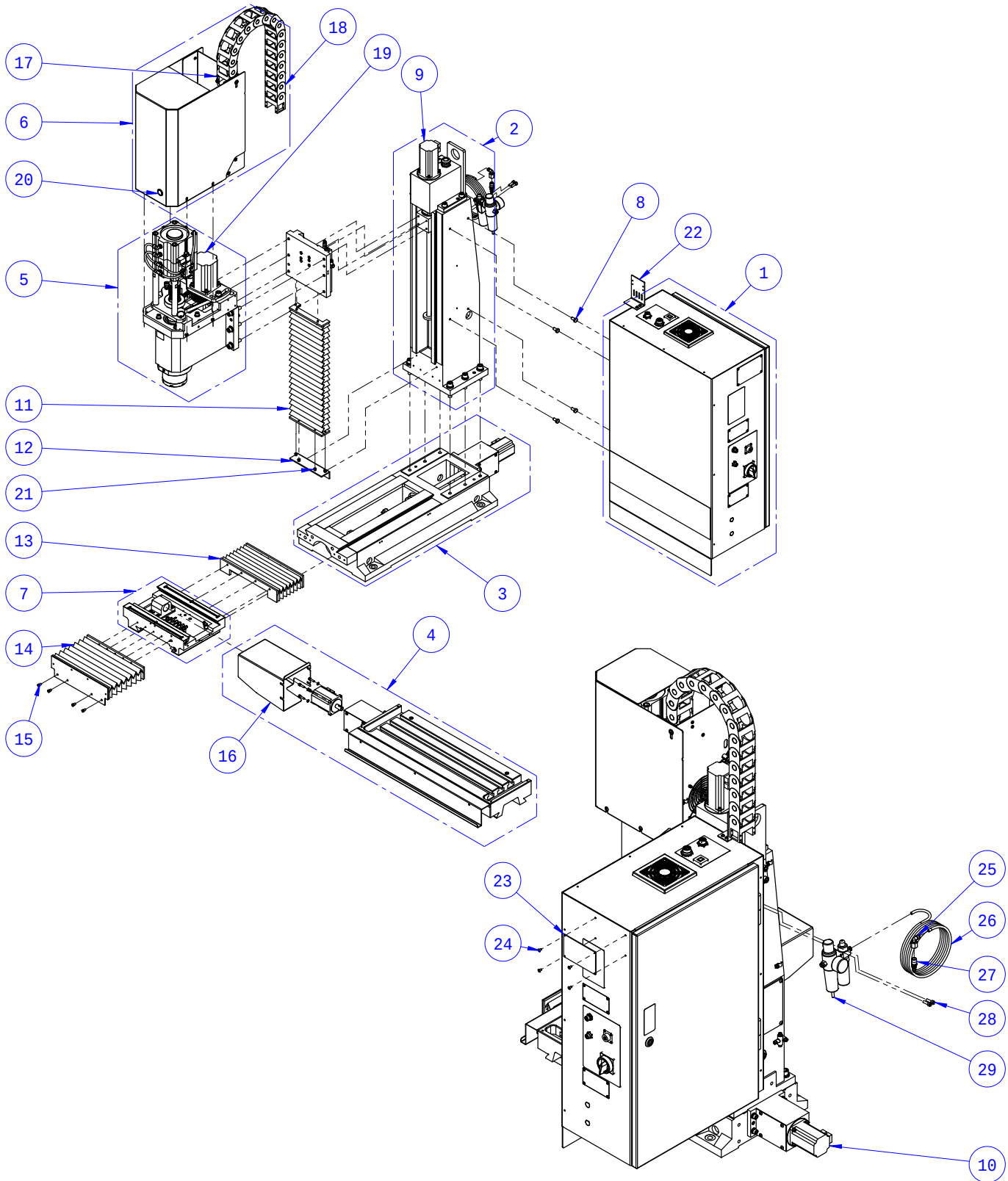
CONTENTS

11.1 Mill Assembly.....	226
11.2 X-Axis Assembly.....	228
11.3 Y-Axis Assembly.....	231
11.4 Y-Axis Saddle Subassembly.....	233
11.5 Z-Axis Assembly.....	235
11.6 Enclosure Assembly.....	238

11: DIAGRAMS AND PARTS LISTS

11.1 Mill Assembly

11.1 MILL ASSEMBLY



11: DIAGRAMS AND PARTS LISTS

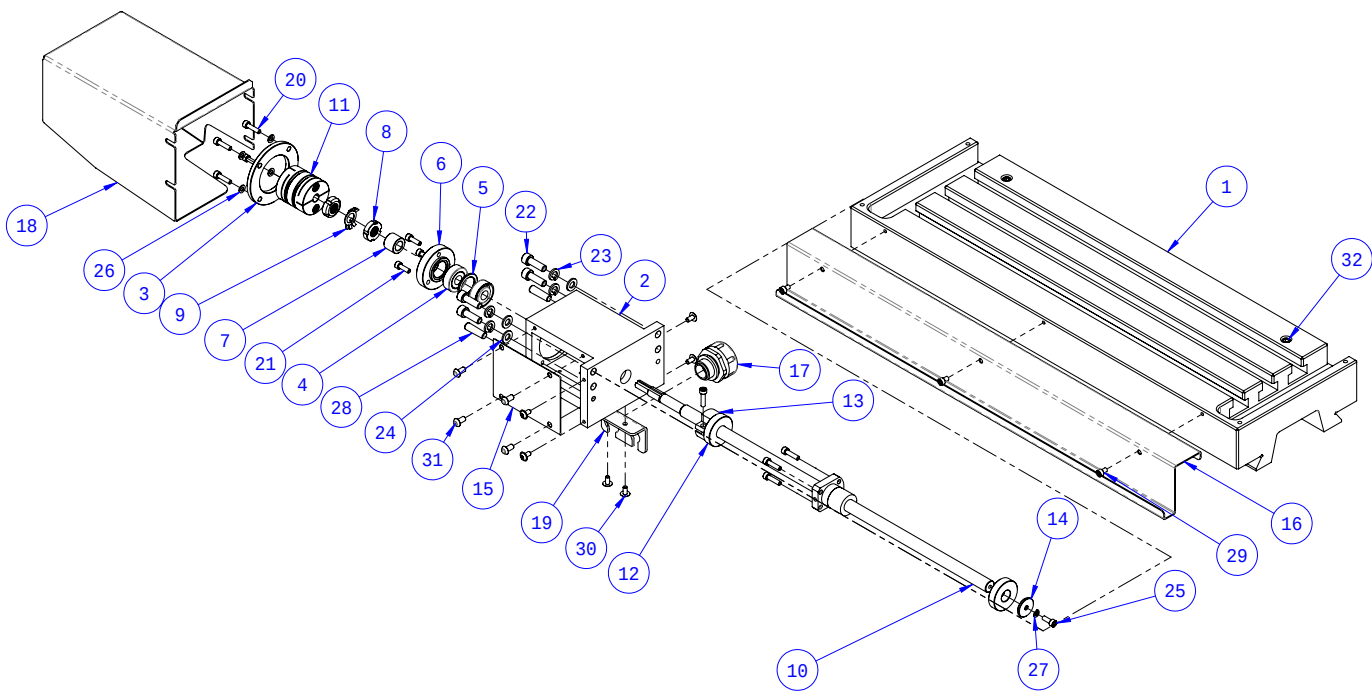
11.1 Mill Assembly

ID	Description	Alternative Part Number	Quantity
1	Electrical Cabinet Assembly, 770MX (PN 54181)	—	1
2	Column Assembly, 770MX (PN 54196)	—	1
3	Y-Axis Subassembly, 770MX (PN 54192)	—	1
4	X-Axis Subassembly, 770MX (PN 54194)	—	1
5	770MX Spindle Head (PN 54198)	—	1
6	Fixed Spindle Cover Front Panel, 770MX (PN 54638)	—	1
7	Saddle Subassembly, 770MX (PN 54215)	—	1
8	Screw, Hex Head Cap, M8 × 1.25 - 16 mm, Hardened Steel (PN 52923)	—	1
9	Servo Motor, 400 W, 220 V, 2.4 A, 3K rpm (7K Max.), Oil Seal and Brake, R Sub-Series (PN 54297)	—	1
10	Servo Motor, 400 W, 220 V, 2.4 A, 3K rpm (7K Max.), Oil Seal, R Sub-Series (PN 54298)	—	2
11	<u>Z-Axis Way Cover, 770 (PN 31433)</u>	—	1
12	Front Drip Guard, 660 mm (PN 50401)	—	1
13	<u>Y-axis Rear Way Cover, 770 (PN 31437)</u>	—	1
14	<u>Y-axis Front Way Cover, 770 (PN 31419)</u>	—	1
15	Screw, Socket Head Cap, M5 × 0.8 - 10 (PN 31641)	McMaster Carr: 91290A224	17
16	X-Axis Motor Cover, 770MX (PN 39277)	—	1
17	Screw, Socket Head Cap, M4 × 0.7 - 45 (PN 54914)	—	8
18	770M Drag Chain (PN 38465)	—	1
19	Servo Motor, 1 kW, 220 V, 6.5 A, 3K rpm (7K Max.), Oil Seal, R Sub-Series (PN 54294)	—	1
20	Push Button, 1NO1NC, White LED (PN 51239)	—	1
21	Screw, Socket Head Cap, M5 × 0.8 - 10 (PN 31641)	McMaster Carr: 91290A224	7
22	770 Lower Drag Chain Mount (PN 38455)	—	1
23	Blind Rivet, 5-32 Diameter, 1-4 Length (PN 52521)	McMaster Carr: 93372A425	4
24	Electrical Cabinet Serial Number Plate, 770MX (PN 54183)	—	1
25	Fitting, Elbow, 1/4 in. Tube - 1/4 in. NPT (Female) (PN 31990)	—	1
26	Tubing, Polyethylene Air Line, 1/4 in. OD, Black (PN 31457)	McMaster-Carr: 5180K71	1
27	Fitting, Brass Coupling, 1/4 Male NPT (PN 31989)	McMaster Carr: 1077T17	1
28	Screw, Socket Head Cap, M6 × 1 - 20 (PN 30832)	McMaster-Carr: 91290A326	2
29	<u>FRL Filter-Regulator-Lubricator (PN 38829)</u>	—	1

11: DIAGRAMS AND PARTS LISTS

11.2 X-Axis Assembly

11.2 X-AXIS ASSEMBLY



11: DIAGRAMS AND PARTS LISTS

11.2 X-Axis Assembly

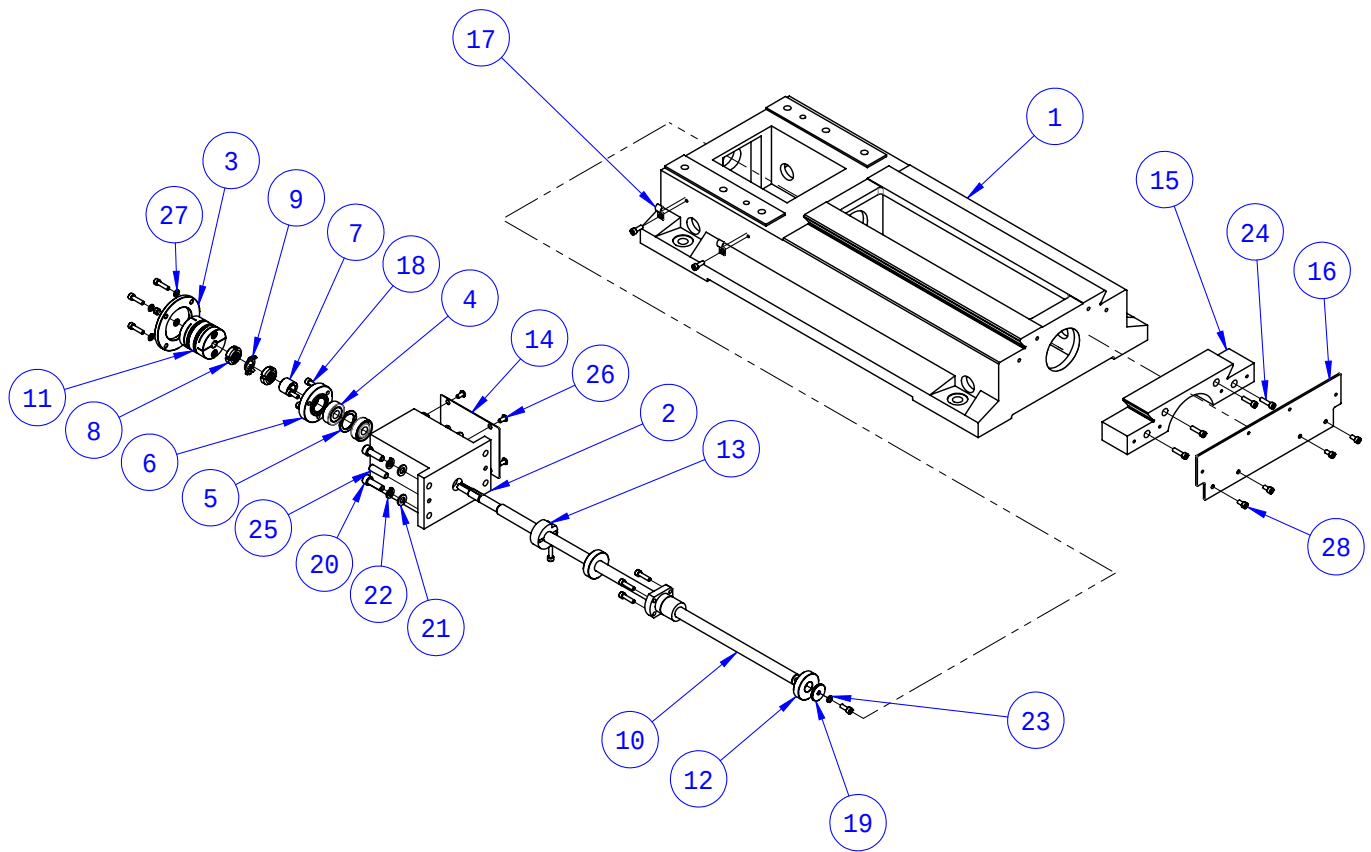
ID	Description	Alternative Part Number	Quantity
1	770 Machine Table (PN 31625)	—	1
2	X-Axis Motor Mount Casting, 770MX (PN 54195)	—	1
3	Axis Motor Adapter Rings, 82 mm OD to 50 mm ID(PN 54218)	—	1
4	<u>X-, Y-, and Z-Axis Ball Screw Support Bearing (PN 31432)</u>	—	2
5	770 X-Y Ball Screw Bearing Spacer (PN 31615)	—	1
6	Bearing Cap (PN 31530)	—	1
7	Sleeve (PN 31537)	—	1
8	<u>M12 × 1.25 X and Y Ball Screw Preload Nut, 770 (PN 31616)</u>	—	2
9	<u>770 Tab Washer for Preload Nut (PN 31542)</u>	—	1
10	<u>X-Axis Ball Screw Assembly, 770 (PN 31423)</u>	—	1
11	Coupler, Double Disc, 10 mm Bore × 14 mm Bore	—	1
12	X/Y-Axis Ball Screw End Bumper, 770 (PN 31613)	—	2
13	770 Ball Screw End Stop Clamp (PN 31614)	—	1
14	Washer, Flat, 5 × 25, 3 mm Thick (PN 31532)	—	1
15	770 X-Y Motor Mount Cover Plate (PN 31621)	—	1
16	Front Drip Guard, 660 mm (PN 50401)	—	1
17	Flex Conduit Fitting, Threaded Adapter (PN 54699)	—	1
18	X-Axis Motor Cover, 770MX (PN 39277)	—	1
19	Flex Conduit Bracket, X-Axis (PN 54222)	—	1
20	Screw, Socket Head Cap, M5 × 0.8 - 20 (PN 30357)	McMaster Carr: 91290A242	9
21	Screw, Socket Head Cap, M5 × 0.8 - 16 (PN 30546)	McMaster- Carr: 91290A232	3
22	Screw, Socket Head Cap, M8 × 1.25 - 25 (PN 34635)	McMaster-Carr: 91290A432	4
23	Washer, Split Lock, M8 (PN 32339)	—	4
24	Washer, Flat, M8 (PN 30531)	McMaster-Carr: 91166A270	4
25	Screw, Socket Head Cap, M5 × 0.8 - 14 (PN 31563)	McMaster Carr: 91290A230	1
26	Washer, Flat, M5 (PN 39305)	McMaster Carr: 91166A240	4
27	Washer, Split Lock, M5 (PN 31572)	—	1
28	Pin, Taper, 8 × 30, M5 Thread (PN 31620)	—	2
29	Screw, Socket Head Cap, M5 × 0.8 - 8 (PN 30844)	McMaster Carr: 91290A222	3
30	Screw, Button Head Cap (Flanged), M5 × 0.8 - 10, Stainless Steel (PN 38205)	McMaster-Carr: 97654A376	6
31	Screw, Button Head Cap, M6 × 1 - 12, Stainless Steel (PN 51597)	McMaster-Carr: 92095A226	4

11: DIAGRAMS AND PARTS LISTS

11.2 X-Axis Assembly

ID	Description	Alternative Part Number	Quantity
32	Screw, Cup Point Set, M12 × 1.75 - 12 (PN 51699)	McMaster-Carr: 91390A169	2

11.3 Y-AXIS ASSEMBLY

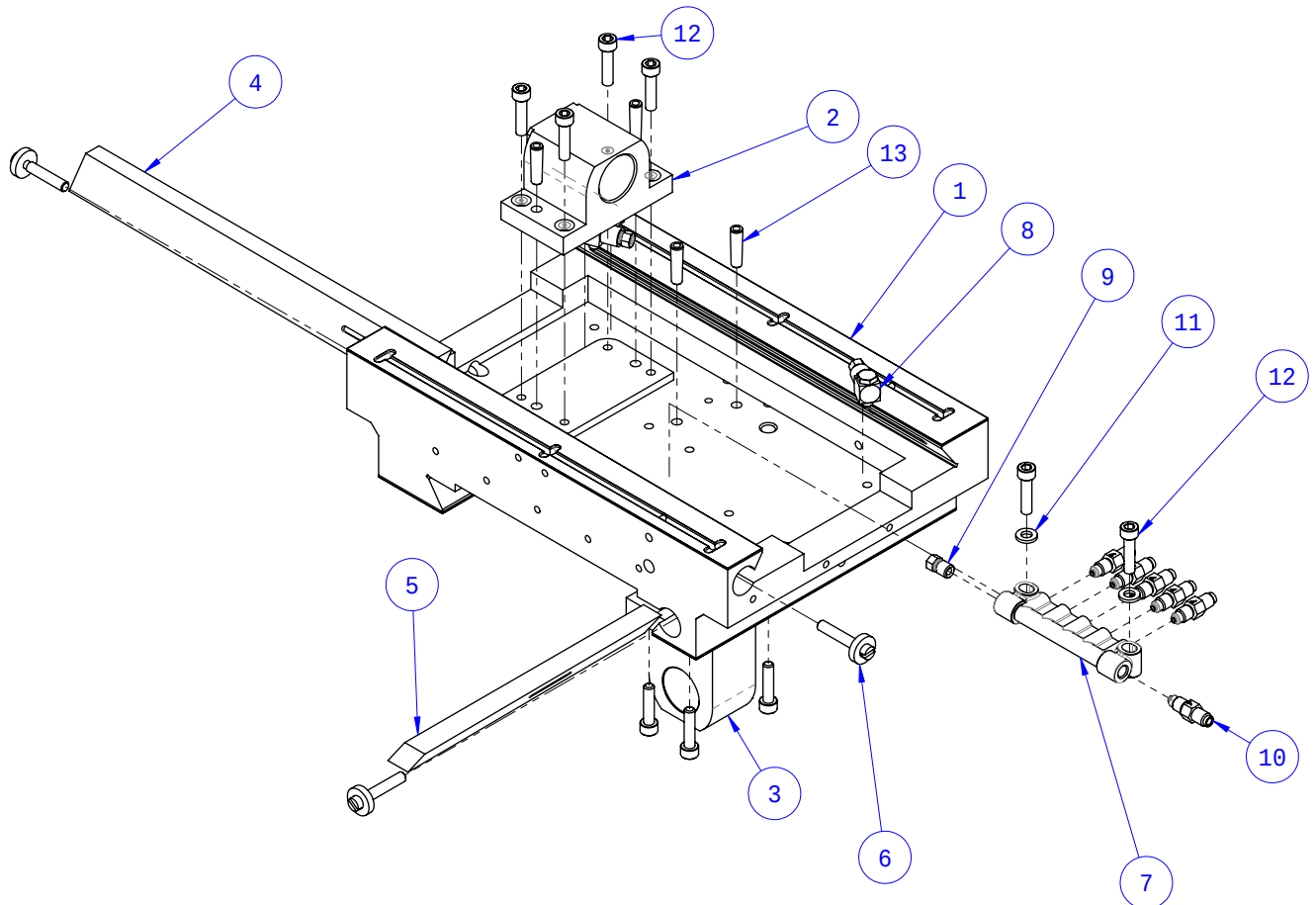


11: DIAGRAMS AND PARTS LISTS

11.3 Y-Axis Assembly

ID	Description	Alternative Part Number	Quantity
1	770 Machine Base (PN 31606)	—	1
2	Y-Axis Motor Mount Casting, 770MX (PN 54193)	—	1
3	Axis Motor Adapter Rings, 82 mm OD to 50 mm ID(PN 54218)	—	1
4	<u>X-, Y-, and Z-Axis Ball Screw Support Bearing (PN 31432)</u>	—	2
5	770 X-Y Ball Screw Bearing Spacer (PN 31615)	—	1
6	Bearing Cap (PN 31530)	—	1
7	Sleeve (PN 31537)	—	1
8	<u>M12 × 1.25 X and Y Ball Screw Preload Nut, 770 (PN 31616)</u>	—	2
9	<u>770 Tab Washer for Preload Nut (PN 31542)</u>	—	1
10	<u>Y-Axis Ball Screw Assembly, 770 (PN 31425)</u>	—	1
11	Coupler, Double Disc, 10 mm Bore × 14 mm Bore	—	1
12	X/Y-Axis Ball Screw End Bumper, 770 (PN 31613)	—	2
13	770 Ball Screw End Stop Clamp (PN 31614)	—	1
14	770 X-Y Motor Mount Cover Plate (PN 31621)	—	1
15	770 Y-Axis Bellows Holder (PN 31627)	—	1
16	Y Cover Mounting Plate (PN 31628)	—	1
17	Routing Clamp (PN 54700)	—	2
18	Screw, Socket Head Cap, M5 × 0.8 - 14 (PN 31563)	McMaster Carr: <u>91290A230</u>	6
19	Washer, Flat, 5 × 25, 3 mm Thick (PN 31532)	—	1
20	Screw, Socket Head Cap, M8 × 1.25 - 25 (PN 34635)	McMaster-Carr: <u>91290A432</u>	4
21	Washer, Flat, M8 (PN 30531)	McMaster-Carr: <u>91166A270</u>	4
22	Washer, Split Lock, M8 (PN 32339)	—	4
23	Washer, Split Lock, M5 (PN 31572)	—	1
24	Screw, Socket Head Cap, M5 × 0.8 - 20 (PN 30357)	McMaster Carr: <u>91290A242</u>	17
25	Pin, Taper, 8 × 30, M5 Thread (PN 31620)	—	2
26	Screw, Button Head Cap, M5 × 0.8 - 10, Stainless Steel (PN 54419)	McMaster Carr: <u>92095A208</u>	4
27	Washer, Flat, M5 (PN 39305)	McMaster Carr: <u>91166A240</u>	4
28	Screw, Socket Head Cap, M5 × 0.8 - 10 (PN 31641)	McMaster Carr: <u>91290A224</u>	17

11.4 Y-AXIS SADDLE SUBASSEMBLY

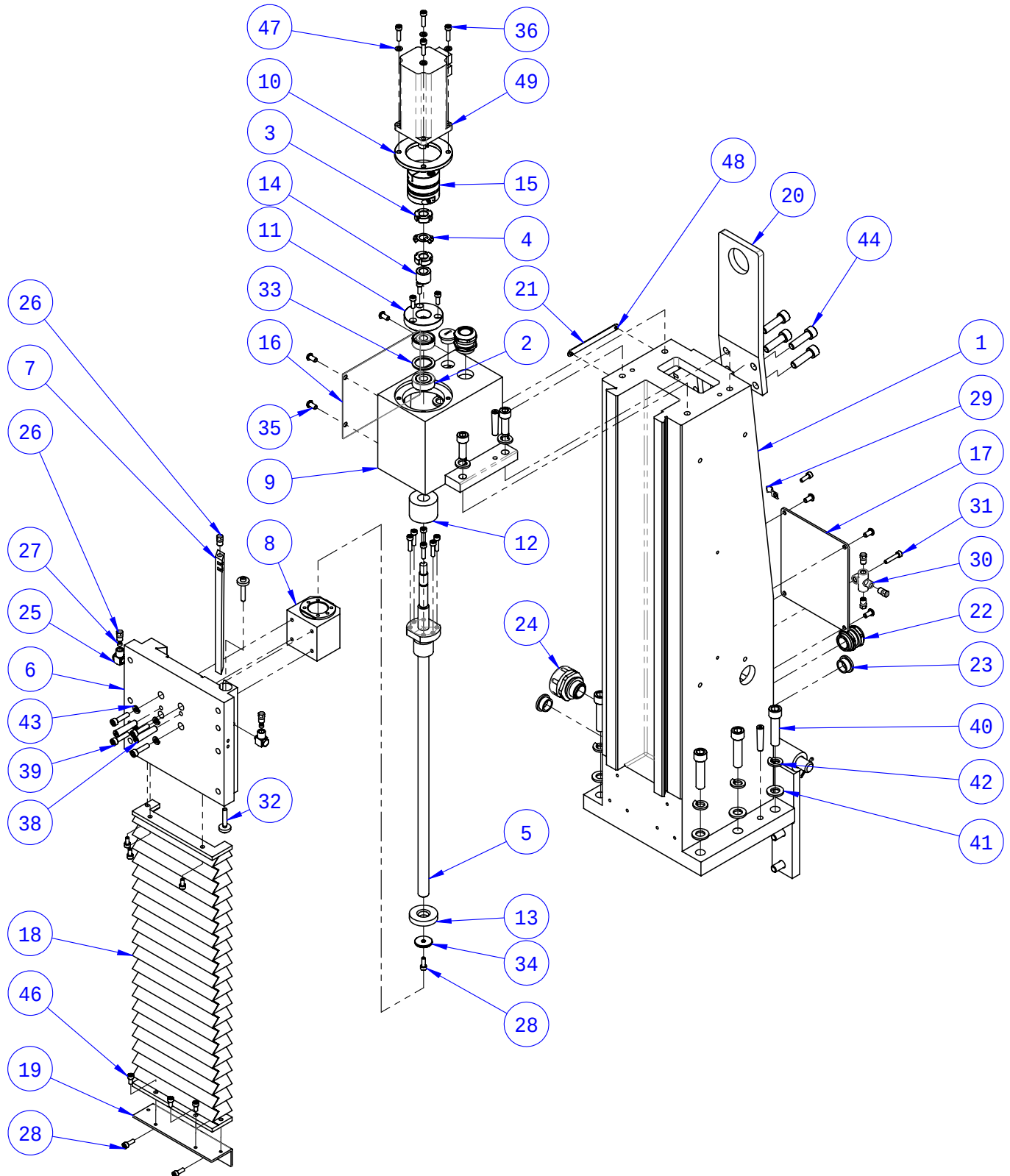


11: DIAGRAMS AND PARTS LISTS

11.4 Y-Axis Saddle Subassembly

ID	Description	Alternative Part Number	Quantity
1	770 Y-Axis Saddle (PN 31607)	—	1
2	X Ball Nut Carrier (PN 31624)	—	1
3	Y Ball Nut Carrier (PN 31608)	—	1
4	770 X-Axis Gib (PN 31631)	—	1
5	770 Y-Axis Gib (PN 31632)	—	1
6	Adjustment Screw (PN 31525)	—	4
7	Fitting, Manifold Union, 7 Ports M8 × P1 (Female), Fits 4 mm Tubing (PN 33955)	—	1
8	<u>Fitting, Banjo Elbow, M6 × 1 - 4 mm Tube (PN 31311)</u>	—	2
9	<u>Fitting, Compression Nut, 4 mm Tube (PN 31310)</u>	—	3
10	Fitting, Flow Restrictor, M8 × P1 (Male) to M8 × P1 (Male), Brass, SBJ-4 (PN 31370)	—	6
11	Washer, Flat, M6 (PN 31676)	McMaster Carr: 91166A250	2
12	Screw, Socket Head Cap, M6 × 1 - 25 (PN 31685)	McMaster-Carr: 91290A330	10
13	<u>Taper Pin, 6 - 25 (PN 30439)</u>	—	4

11.5 Z-AXIS ASSEMBLY



11: DIAGRAMS AND PARTS LISTS

11.5 Z-Axis Assembly

ID	Description	Alternative Part Number	Quantity
1	Column Casting, 770MX (PN 54216)	—	1
2	<u>X-, Y-, and Z-Axis Ball Screw Support Bearing (PN 31432)</u>	—	2
3	<u>Z-Axis Ball Screw Preload Nut for 770 (PN 31541)</u>	—	2
4	<u>770 Tab Washer for Preload Nut (PN 31542)</u>	—	1
5	<u>Z-Axis Ballscrew Assembly, 770 (PN 31434)</u>	—	1
6	Z-Axis Slide (PN 31523)	—	1
7	Z-Axis Gib (PN 31524)	—	1
8	770 Z Ball Nut Carrier (PN 38864)	—	1
9	Z-Axis Motor Base (PN 31528)	—	1
10	Axis Motor Adapter Rings, 82 mm OD to 50 mm ID(PN 54218)	—	1
11	Bearing Cap (PN 31530)	—	1
12	Z-Axis Ball Screw Upper Bumper, 770 (PN 31531)	—	1
13	<u>Z-Axis Ballscrew Lower Bumper, 770 (PN 31533)</u>	—	1
14	Sleeve (PN 31537)	—	1
15	Coupler, Double Disc, 10 mm Bore × 14 mm Bore	—	1
16	Side Mounting Plate (PN 31538)	—	1
17	Column Cover Plate (PN 31583)	—	1
18	<u>Z-Axis Way Cover, 770 (PN 31433)</u>	—	1
19	Lower Bellows Mounting Plate (PN 31584)	—	1
20	770 Lifting Bracket (PN 31591)	—	1
21	Subssembly PN/SN Tag, 770MX	—	1
22	Cord Grip, M25 × 1.5, 10 mm-16 mm Cord, Stainless Steel (PN 54695)	McMaster Carr: <u>7680K28</u>	2
23	Hole Plug, Threaded, M25 × 1.5 (PN 54696)	—	3
24	Flex Conduit Fitting, Threaded Adapter (PN 54699)	—	1
25	<u>Fitting, Banjo Elbow, M6 × 1 - 4 mm Tube (PN 31311)</u>	—	2
26	<u>Fitting, Compression Nut, 4 mm Tube (PN 31310)</u>	—	6
27	<u>Fitting, Ferrule, 4 mm Tube (PN 31309)</u>	—	6
28	Screw, Socket Head Cap, M5 × 0.8 - 14 (PN 31563)	McMaster Carr: <u>91290A230</u>	8
29	Routing Clamp (PN 54700)	—	2
30	Fitting, Tee, 4 mm Tube, M8 × 1.0 Thread (PN 32354)	—	1
31	Screw, Socket Head Cap, M5 × 0.8 - 25 (PN 30530)	McMaster Carr: <u>91290A252</u>	1

11: DIAGRAMS AND PARTS LISTS

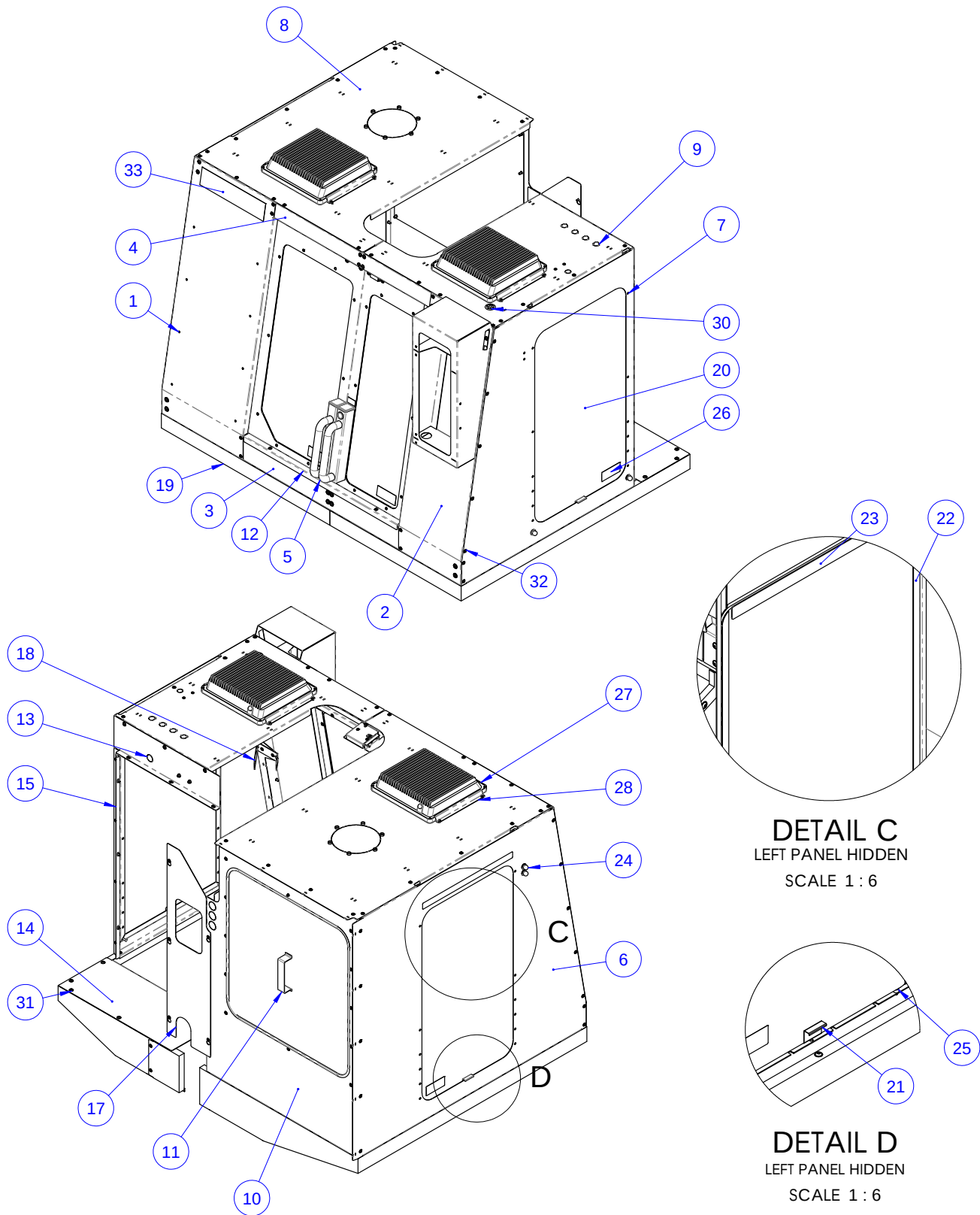
11.5 Z-Axis Assembly

ID	Description	Alternative Part Number	Quantity
32	Adjustment Screw (PN 31525)	—	2
33	Bearing Spacer (PN 31529)	—	1
34	Washer, Flat, 5 × 25, 3 mm Thick (PN 31532)	—	1
35	Screw, Button Head Cap, M6 × 1 - 12, Stainless Steel (PN 51597)	McMaster-Carr: 92095A226	8
36	Screw, Socket Head Cap, M5 × 0.8 - 20 (PN 30357)	McMaster Carr: 91290A242	10
37	Screw, Socket Head Cap, M10 × 1.5 - 30 (PN 31894)	McMaster Carr: 91290A522	4
38	<u>Tapered Dowel Pin, 8 × 40 mm (PN 31544)</u>	—	6
39	Screw, Socket Head Cap, M6 × 1 - 25 (PN 31685)	McMaster-Carr: 91290A330	4
40	Screw, Socket Head Cap, M12 × 1.75 - 50 (PN 32476)	McMaster-Carr: 91290A626	6
41	Washer, Flat, M12 (PN 32473)	McMaster Carr: 91166A290	6
42	Washer, Split Lock, M12 (PN 30321)	—	10
43	Washer, Split Lock, M6 (PN 31379)	—	4
44	Screw, Socket Head Cap, M10 × 1.5 - 35 (PN 31592)	McMaster-Carr: 91290A526	4
45	Washer, Split Lock, M5 (PN 31572)	—	1
46	Screw, Socket Head Cap, M5 × 0.8 - 10 (PN 31641)	McMaster Carr: 91290A224	7
47	Washer, Flat, M5 (PN 39305)	McMaster Carr: 91166A240	4
48	Screw Nail, #4 × 0.188 in., Stainless Steel (PN 51717)	McMaster Carr: 91654A105	2
49	Inovance MS1 Servo Motor (PN 51197)	—	1
50	Hinge Assembly, 770 Moving Kit (PN 50457) (Optional)	—	1

11: DIAGRAMS AND PARTS LISTS

11.6 Enclosure Assembly

11.6 ENCLOSURE ASSEMBLY



11: DIAGRAMS AND PARTS LISTS

11.6 Enclosure Assembly

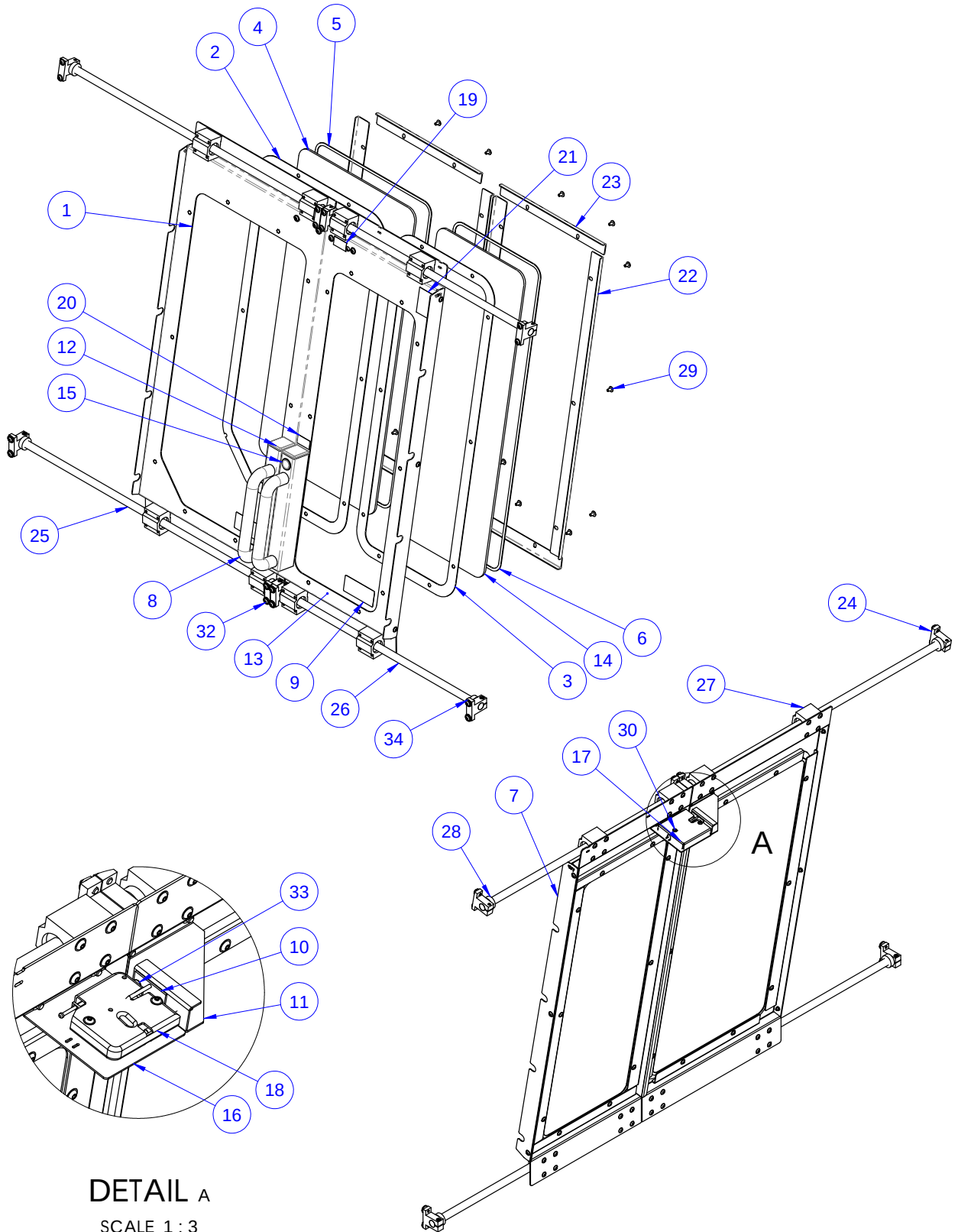
ID	Description	Description	Quantity
1	Enclosure Panel, 770MX, Left Front (PN 39551)	—	1
2	Right Front Enclosure Panel, 770MX (PN 54332)	—	1
3	Lower Front Enclosure Panel, 770MX (PN 54399)	—	1
4	Upper Front Enclosure Panel, 770 (PN 37605)	—	1
5	Enclosure Door Assembly, 770MX (PN 54335)	—	1
6	Enclosure Panel, 770MX, Left Side (PN 54368)	—	1
7	Right Side Enclosure Panel, 770MX (PN 54367)	—	1
8	Left Top Enclosure Panel, 770MX (PN 54370)	—	1
9	Right Top Enclosure Panel, 770MX (PN 54369)	—	1
10	Left Rear Enclosure Panel, 770 (PN 37616)	—	1
11	ATC Cover Panel, 770 (PN 37617)	—	1
12	Chip Tray/Enclosure Scuff Guard, 770 (PN 37662)	—	1
13	Right Rear Enclosure Panel, 770MX (PN 37619)	—	1
14	Enclosure Panel, 770MX, Splash Shield (PN 39555)	—	1
15	Right Rear Enclosure Splice Panel, 770 (PN 38480)	—	1
16	Left Rear Enclosure Splice Panel, 770 (PN 37618)	—	1
17	Column Cover Enclosure Panel, 770MX (PN 54358)	—	1
18	Enclosure Mount Camera Bracket, 1500MX (PN 51417)	—	1
19	Chip Tray Kit, 770MX (PN 54500)	—	1
20	Window, 770, Side (PN 37625)	—	2
21	Finger Pull, Edge Mount (6 mm) (PN 53684)	—	2
22	Enclosure Panel Felt Strips, 770MX (PN 54359)	—	2
23	Enclosure Panel Felt Strips, 770MX (PN 54360)	—	2
24	Enclosure Window Pin, Magnetic (PN 51534)	—	4
25	Push-In Bumper, 0.25 in. Stem, 0.22 in. Height (PN 51367)	McMaster-Carr: 9309K64	4
26	Decal Kit, Mill Enclosure Safety (PN 38830)	—	2
27	LED Floodlight, 50 W (PN 37341)	—	2
28	Flood Light Retainer (PN 38222)	—	4
29	770M Access Panel Trim Rubber Window Trim	—	1
30	Expandable Locking Grommet, 7/8 in. × 1 1/4 in. × 1/32 in. - 1/8 in., Nylon (PN 51519)	McMaster-Carr: 4946A704	1

11: DIAGRAMS AND PARTS LISTS

11.6 Enclosure Assembly

ID	Description		Quantity
31	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	McMaster-Carr: 97654A380	32
32	Screw, Button Head Cap (Flanged), M5 × 0.8 - 10, Stainless Steel (PN 38205)	McMaster-Carr: 97654A376	95
33	Decal, 770MX Enclosure, Front Left Panel (PN 54649)	—	1
34	Wired Probe Bracket Assembly (TTS) (PN 53816)	—	1

11.6.1 Enclosure Door Assembly



11: DIAGRAMS AND PARTS LISTS

11.6 Enclosure Assembly

ID	Description		Quantity
1	Left Enclosure Door Panel, 770MX (PN 54334)	—	1
2	Sealing Strip (Self-Adhesive), 25 mm × 1.5 mm (PN 51693)	McMaster-Carr: 9023K81	1
3	Sealing Strip (Self-Adhesive), 25 mm × 1.5 mm (PN 51693)	McMaster-Carr: 9023K81	1
4	Window, 770M, Left Door (PN 37623)	—	1
5	Sealing Strip (Self-Adhesive), 6 mm × 1.5 mm (PN 54714)	—	1
6	Sealing Strip (Self-Adhesive), 6 mm × 1.5 mm (PN 54714)	—	1
7	Door Seal (PN 37613)	—	2
8	Door Handle (PN 51361)	—	2
9	Decal Kit, Mill Enclosure Safety (PN 38830)	—	2
10	Locking Door Switch Latch Plate (PN 51329)	—	1
11	Door Switch Latch Bracket, Front Mount (PN 54341)	—	1
12	Enclosure Door Handle Mount Plug, 45 mm × 38 mm (PN 55029)	—	2
13	Right Door (PN 37609)	—	1
14	Window, 770M, Right Door (PN 37624)	—	1
15	Push Button, 1NO1NC, White LED (PN 51239)	—	1
16	Door Switch Bracket, Front Mount (PN 54331)	—	1
17	Door Switch Cover, Front Mount (PN 54715)	—	1
18	Locking Door Switch (PN 51328)	—	1
19	Label, Door Latch Manual Override (PN 54703)	—	1
20	Label, Unlock Door (PN 54704)	—	1
21	Label, Caution Enclosure Entry Prohibited (PN 54705)	—	1
22	Long Window Retainer, 770MX (PN 54337)	—	4
23	Short Window Retainer, 770MX (PN 54338)	—	4
24	Linear Rail Support, Round, 16 mm (PN 37622)	—	8
25	Linear Rail, 16 mm Round, 776 mm (PN 37606)	—	2
26	Linear Rail, 16 mm Round, 601 mm (PN 37607)	—	2
27	Linear Bearing Block, 16 mm Round Rail, M5 Mounting Holes	—	8
28	Door Bumper (PN 38357)	—	8
29	Screw, Button Head Cap (Flanged), M5 × 0.8 - 10, Stainless Steel (PN 38205)	McMaster-Carr: 97654A376	59
30	Screw, Button Head Cap, Flanged M4 × 0.7 - 8, 18-8 Stainless (PN 51331)	McMaster-Carr: 97654A372	6

11: DIAGRAMS AND PARTS LISTS

11.6 Enclosure Assembly

ID	Description		Quantity
31	Screw, Button Head Cap, Flanged M8 × 1.25 - 16, 18-8 Stainless (PN 38468)	McMaster-Carr: 90909A479	4
32	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	McMaster-Carr: 97654A380	20
33	Screw, Socket Head Countersunk, M4 × 0.7 - 8, Stainless Steel (PN 51672)	McMaster-Carr: 92125A188	2
34	Washer, Bonded Neoprene Seal, 1/4 in. × 5/8 in., 0.114 in. Thick, 18-8 Stainless	—	8



ELECTRICAL SCHEMATICS

IN THIS SECTION, YOU'LL LEARN:

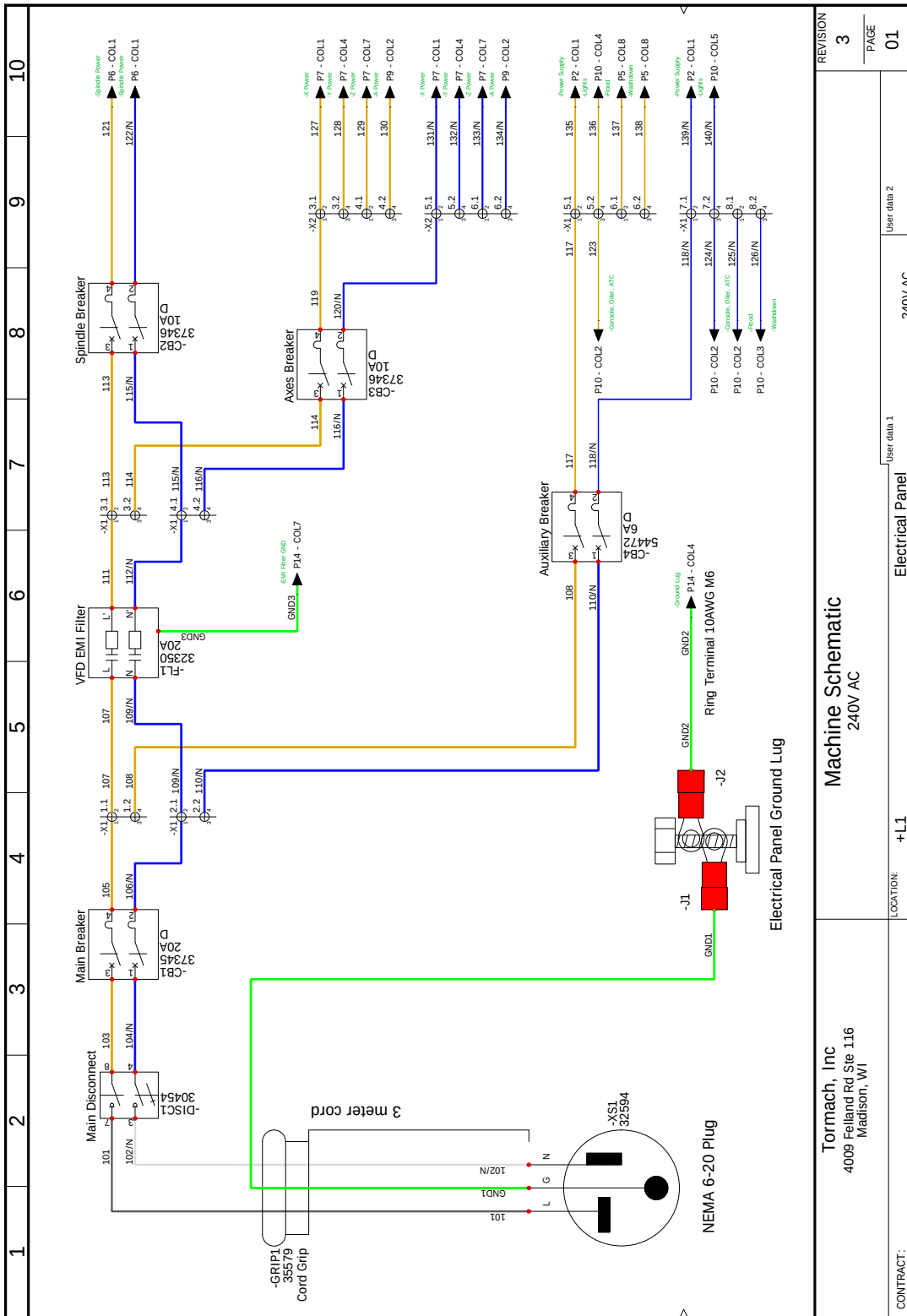
- About the electrical schematics for this machine's electronics.

CONTENTS

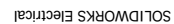
12.1 240 Vac Power (Page 1).....	246
12.2 24 Vdc/75 Vdc Power (Page 2).....	247
12.3 Breakout Board - Digital Inputs and Outputs (Page 3).....	248
12.4 Breakout Board - Power, Drives, Aux Outputs, and Safety (Page 4).....	249
12.5 Breakout Board - Aux Inputs, Brakes, and Vac Control (Page 5).....	250
12.6 Spindle Drive (Page 6).....	251
12.7 XYZ Axis Drives (Page 7).....	252
12.8 A-Axis Stepper Drive (microARC 4) (Page 8).....	253
12.9 A-Axis Servo Drive (microARC 6) (Page 9).....	254
12.10 Accessory/Aux (Page 10).....	255
12.11 Operator Panel (Page 11).....	256
12.12 Enclosure (Page 12).....	257
12.13 Power Drawbar (Page 13).....	258
12.14 Grounds (Page 14).....	259
12.15 Terminal Strip - AC (X1) (Pages 15-16).....	260
12.16 Terminal Strip- Drive Power (X2) (Pages 17-18).....	262
12.17 Terminal Strip - DC (X3) (Page 19).....	264
12.18 Terminal Strip - Grounds (X4) (Page 20).....	265
12.19 Bill of Materials (Pages 21-22).....	266

12.1 240 Vac Power (Page 1)

12.1 240 VAC POWER (PAGE 1)

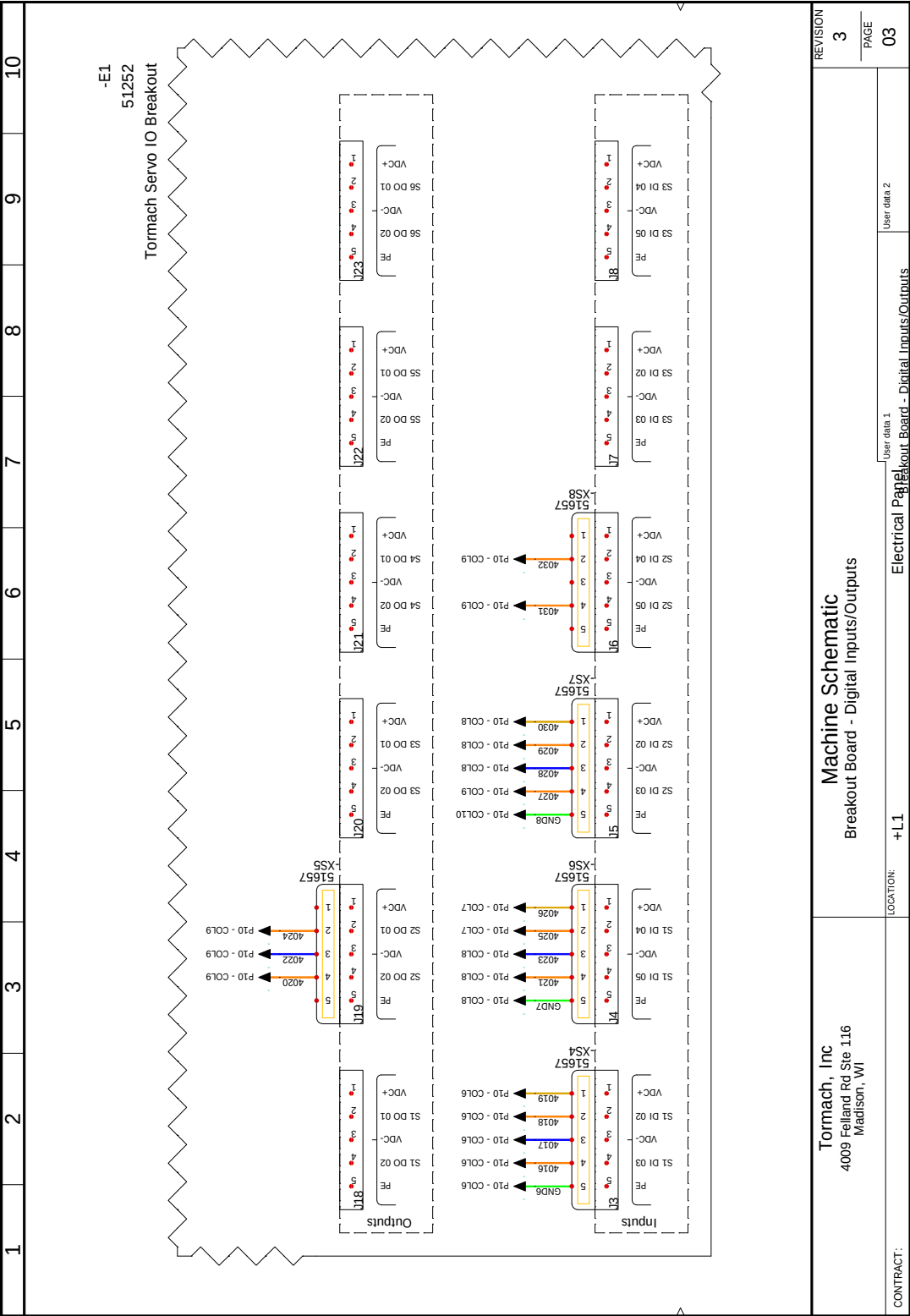


12.2 24 VDC/75 VDC POWER (PAGE 2)



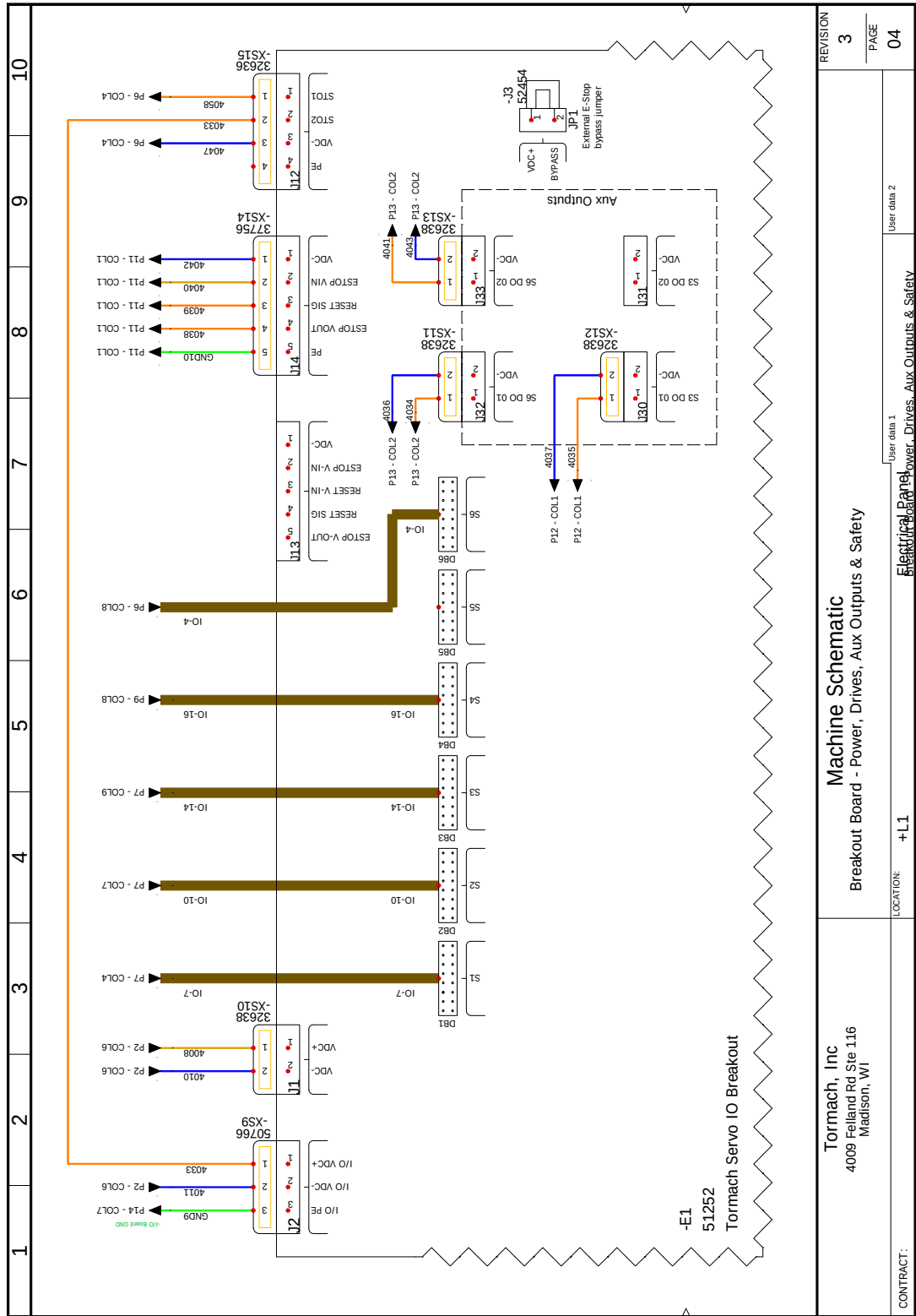
12: ELECTRICAL SCHEMATICS
12.3 Breakout Board - Digital Inputs and Outputs (Page 3)

12.3 BREAKOUT BOARD - DIGITAL INPUTS AND OUTPUTS (PAGE 3)



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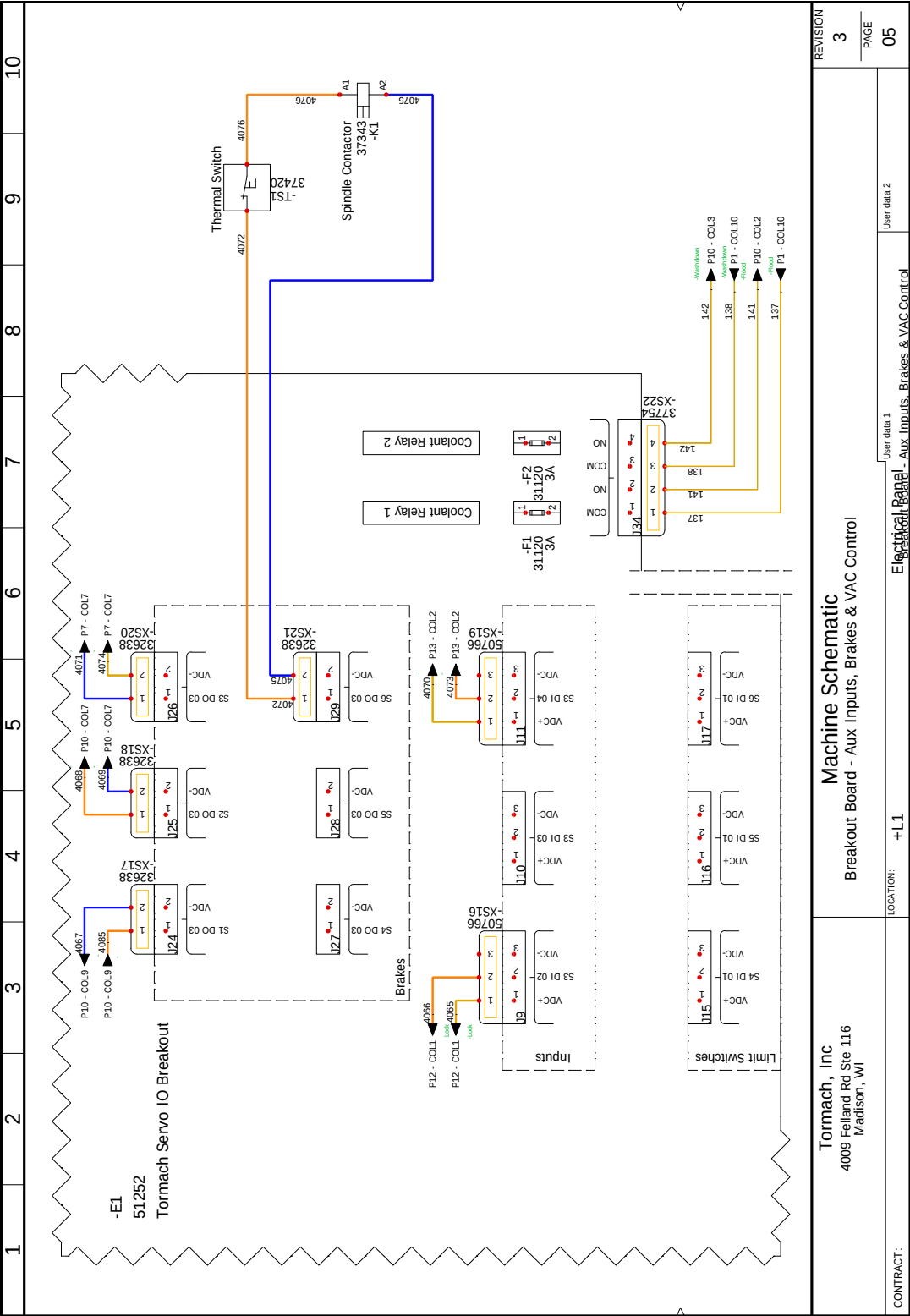
12.4 BREAKOUT BOARD - POWER, DRIVES, AUX OUTPUTS, AND SAFETY (PAGE 4)



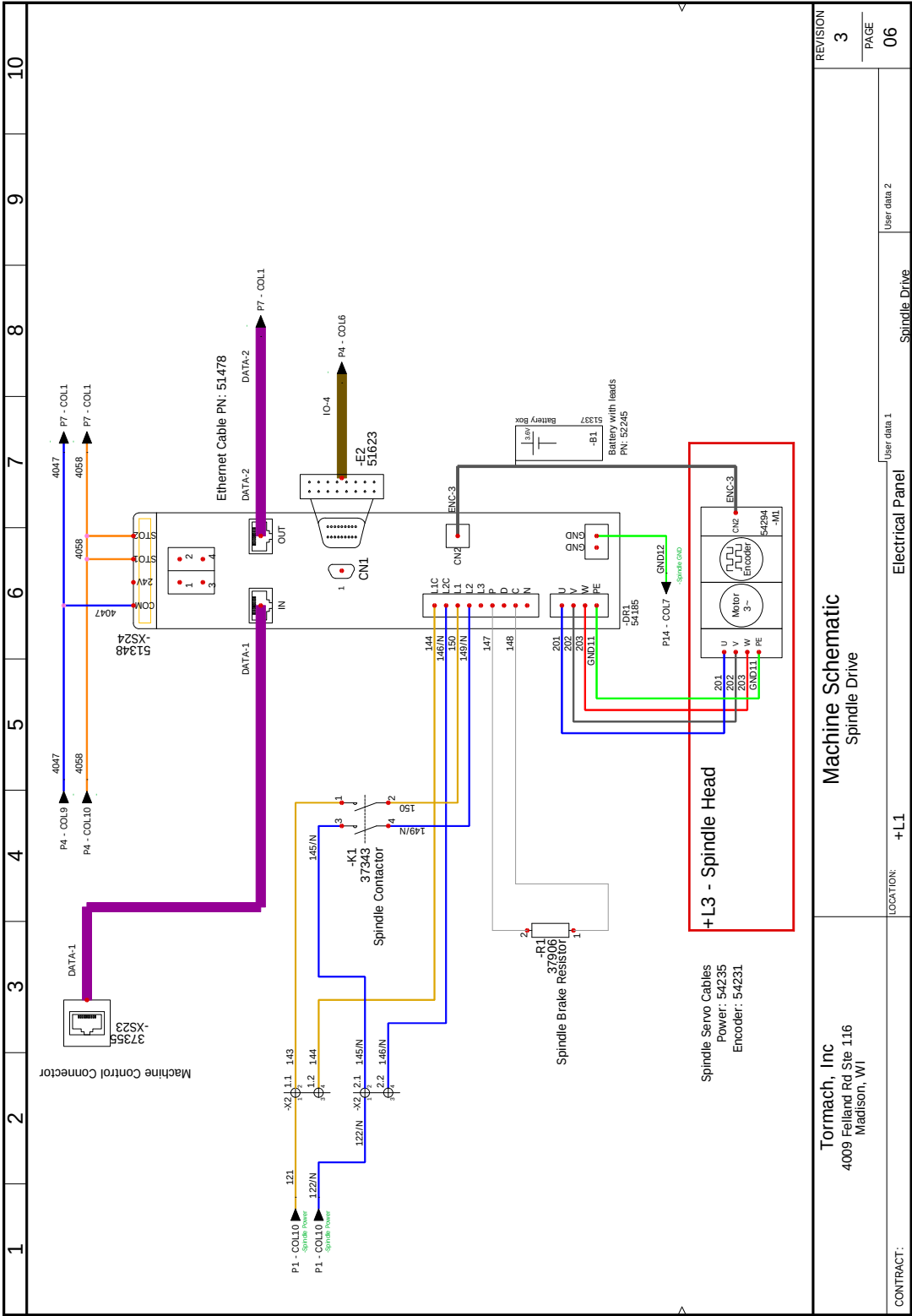
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12: ELECTRICAL SCHEMATICS
12.5 Breakout Board - Aux Inputs, Brakes, and Vac Control (Page 5)

12.5 BREAKOUT BOARD - AUX INPUTS, BRAKES, AND VAC CONTROL (PAGE 5)

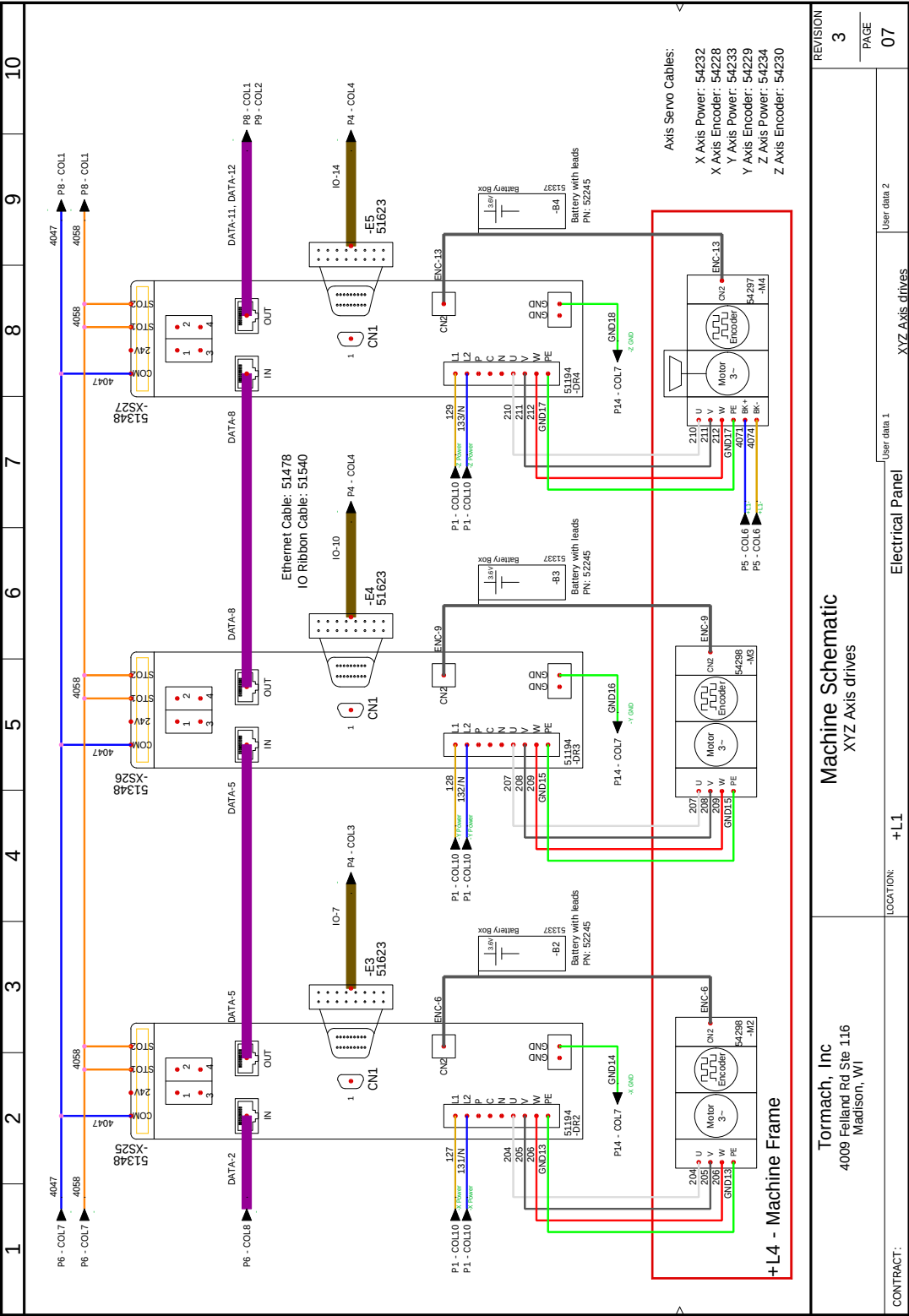


12.6 SPINDLE DRIVE (PAGE 6)



12: ELECTRICAL SCHEMATICS
12.7 XYZ Axis Drives (Page 7)

12.7 XYZ AXIS DRIVES (PAGE 7)

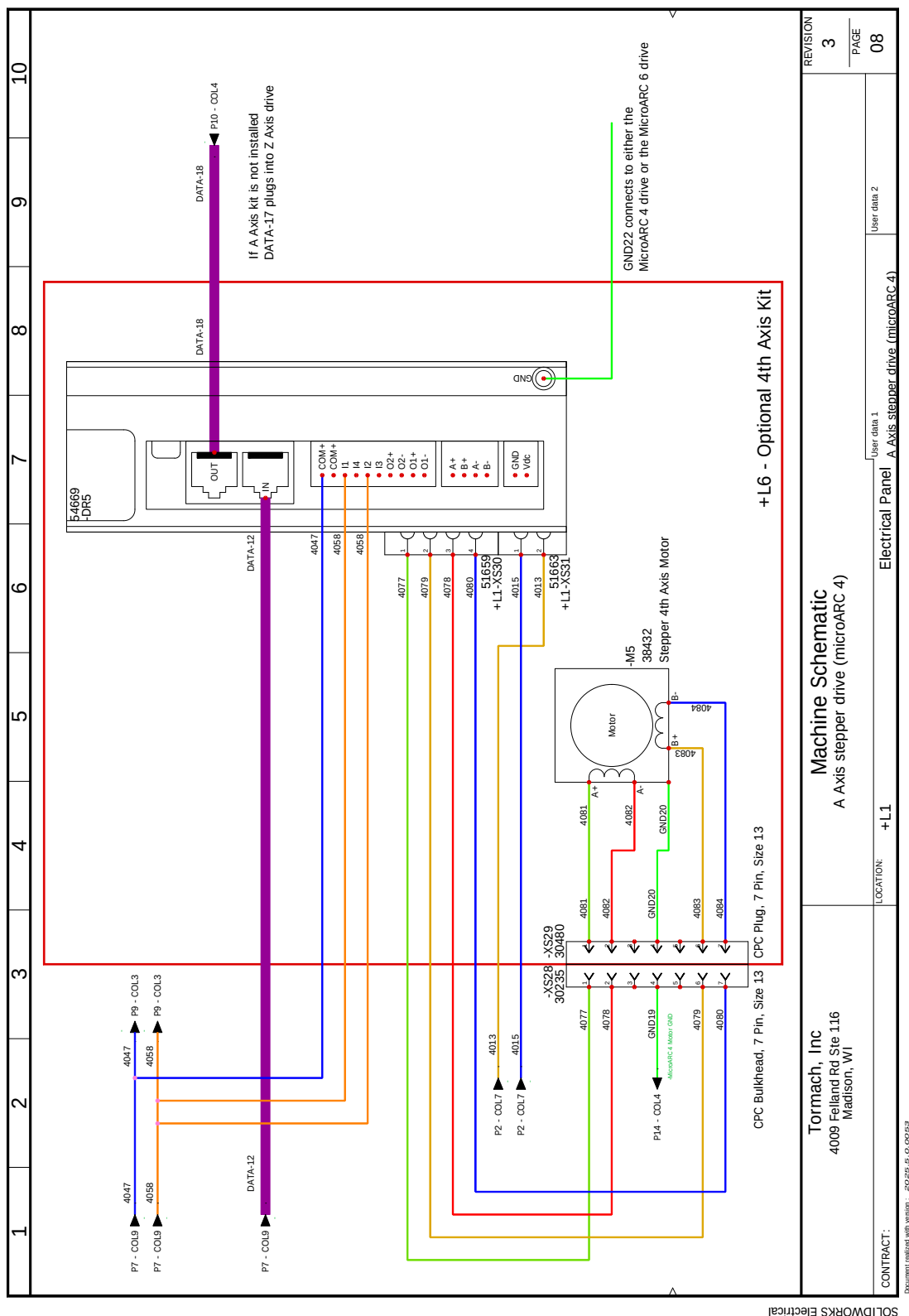


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Tormach, Inc 4009 Felland Rd Ste 116 Madison, WI	Machine Schematic XYZ Axis drives	LOCATION: +L1	Electrical Panel	User data 1	User data 2	REVISION
						3 PAGE 07

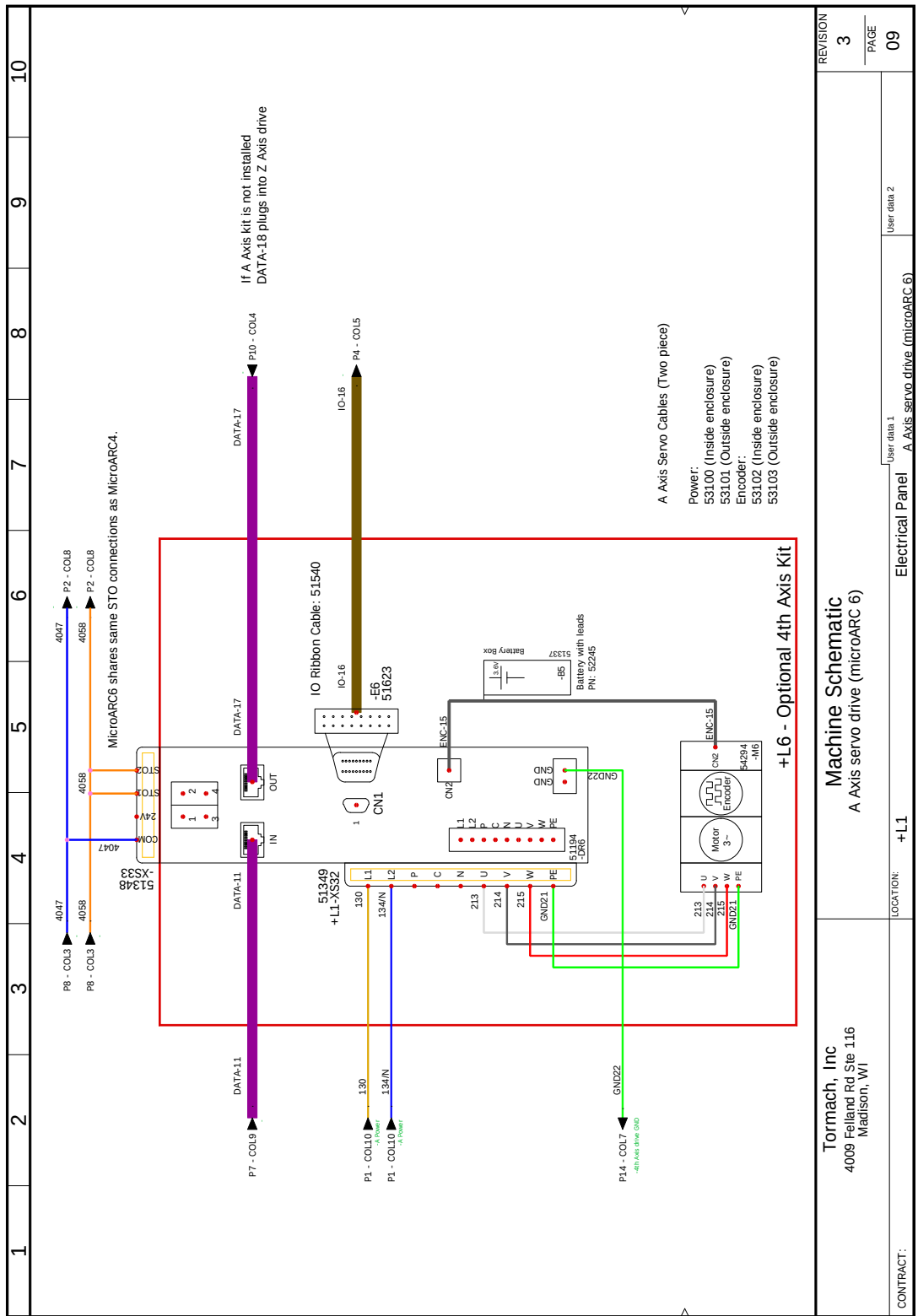
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12.8 A-AXIS STEPPER DRIVE (MICROARC 4) (PAGE 8)

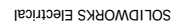


12.9 A-Axis Servo Drive (microARC 6) (Page 9)

12.9 A-AXIS SERVO DRIVE (MICROARC 6) (PAGE 9)

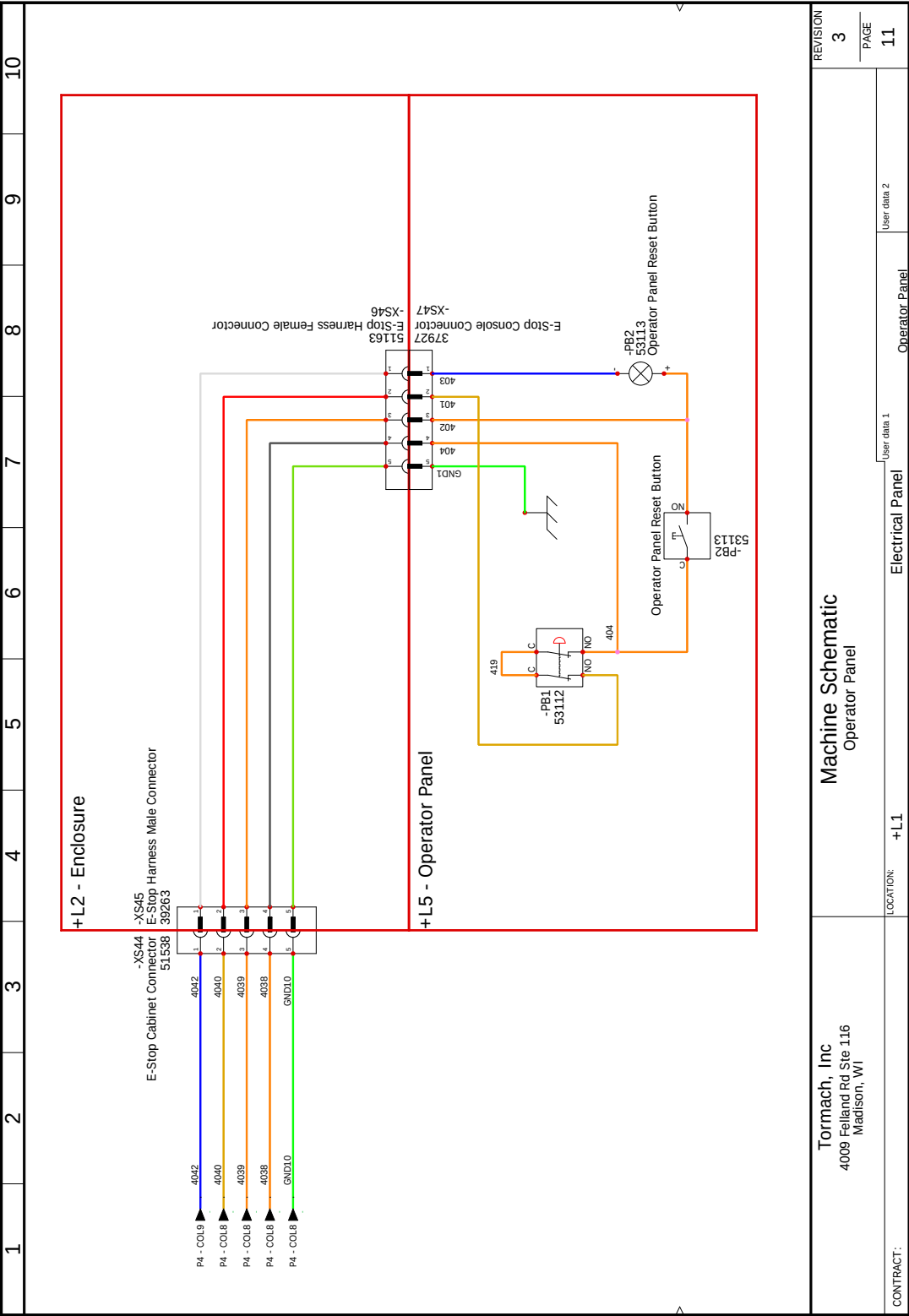


12.10 ACCESSORY/AUX (PAGE 10)



12: ELECTRICAL SCHEMATICS
12.11 Operator Panel (Page 11)

12.11 OPERATOR PANEL (PAGE 11)



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Tormach, Inc 4009 Felland Rd Ste 116 Madison, WI	Machine Schematic Operator Panel		REVISION 3
	CONTRACT:	LOCATION: +L1	PAGE 11
User data 1		Operator Panel	User data 2

Document released with version: 2025.05.03.00153

1	2	3	4	5	6	7	8	9	10
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+L2 - Enclosure

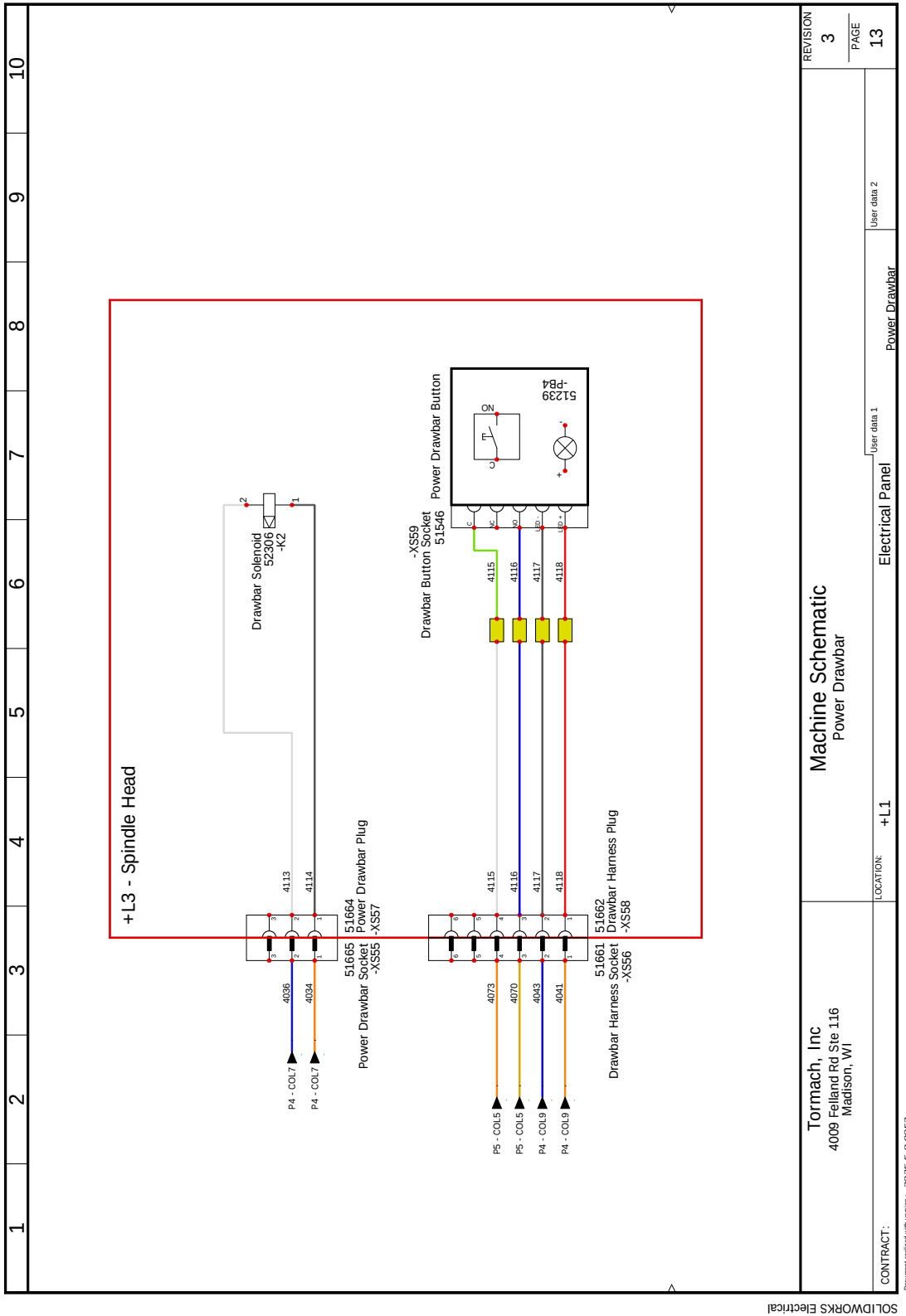
The diagram illustrates the electrical wiring for a Machine Schematic Enclosure. It shows the following components and their connections:

- Door Safety Cabinet Connector -XS48** (51659) with terminals 1-4 connected to **P5 - COL3** (4065), **P5 - COL3** (4066), **P4 - COL7** (4035), and **P4 - COL7** (4037).
- Door Safety Harness Connector -XS49** (51660) with terminals 1-4 connected to **4098**, **4099**, **4100**, and **4101**.
- 51801 -XS50** (4098) and **51801 -XS53** (4099) are connected to **4109** and **4110**.
- 51801 -XS51** (4104) and **51801 -XS54** (4111) are connected to **4103** and **4112**.
- Lock Switch** (4110) and **Lock Solenoid -DS1** (51328) are connected to **4111** and **4112**.
- Door Latch Button Socket** (51546) with terminals **+L1-XS52** (4100), **-PB3** (4104), **-PB3** (4102), and **-PB3** (4101).
- Door Latch Button** (51239) with terminals **+PB3** (4100), **-PB3** (4104), **-PB3** (4102), and **-PB3** (4101).

CONTRACT:	Tormach, Inc 4009 Feland Rd Ste 116 Madison, WI	Machine Schematic Enclosure		REVISION
		LOCATION: +L1	Electrical Panel	3
			User data 1	PAGE
			Enclosure	12

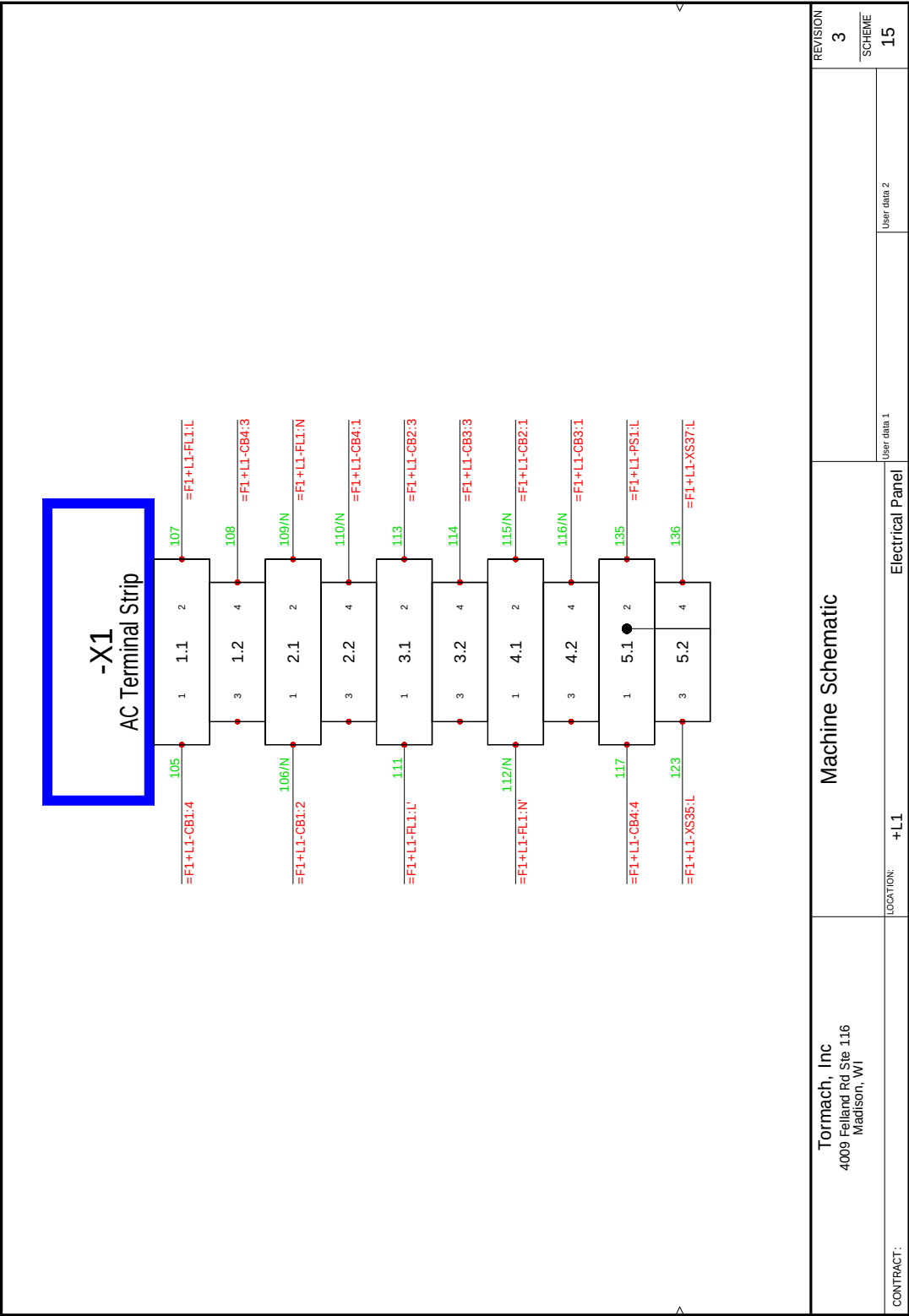
12.13 Power Drawbar (Page 13)

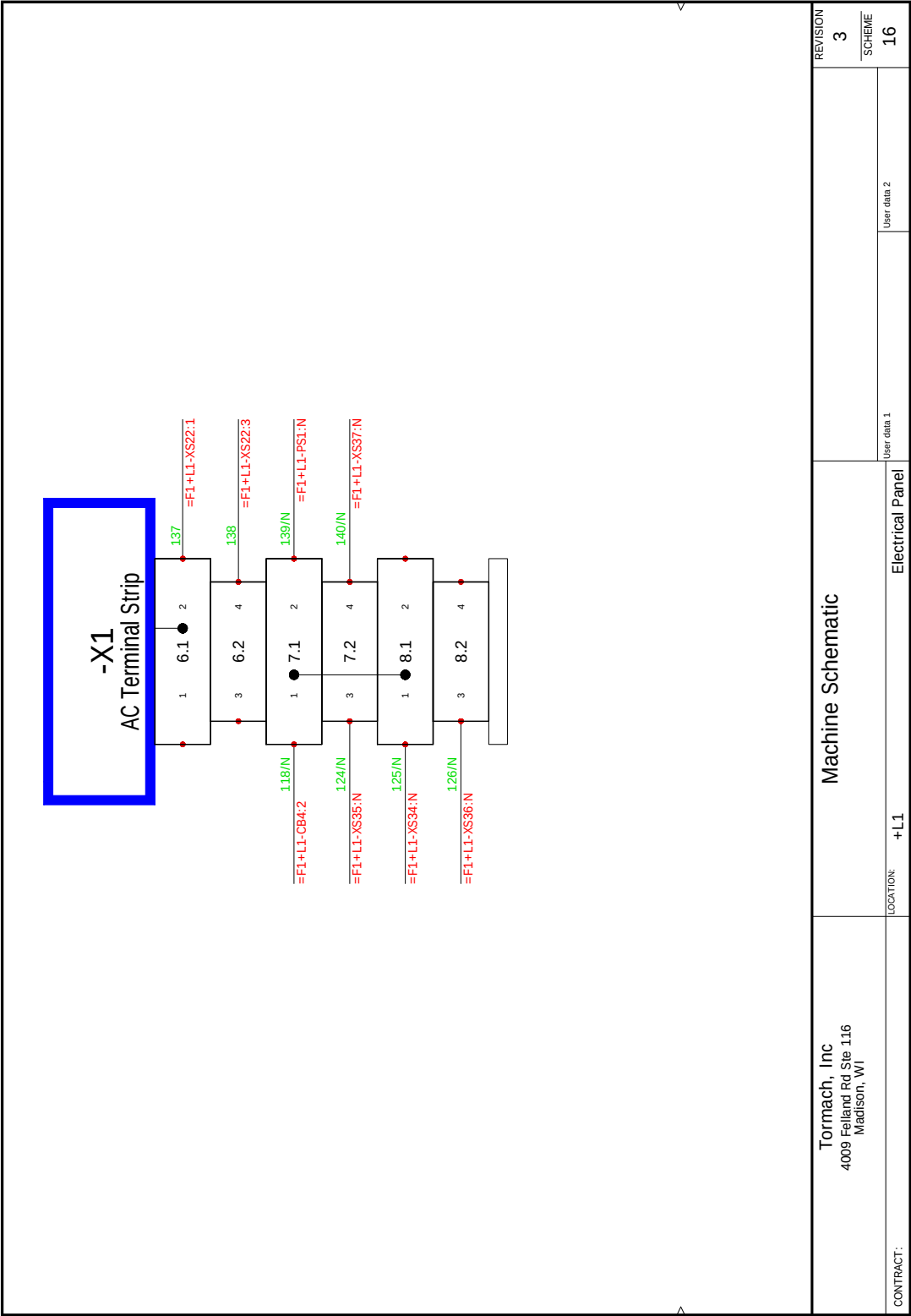
12.13 POWER DRAWBAR (PAGE 13)



12: ELECTRICAL SCHEMATICS
12.15 Terminal Strip - AC (X1) (Pages 15-16)

12.15 TERMINAL STRIP - AC (X1) (PAGES 15-16)





3

8.2

4

126/N

=F1+L1-XS36:N

118/N

=F1+L1-CB4:2

124/N

=F1+L1-XS35:N

-X1

AC Terminal Strip

1

6.1

2

3

6.2

4

1

7.1

2

3

7.2

4

1

8.1

2

3

8.2

4

REVISION

3

SCHEME

16

Machine Schematic

Electrical Panel

Tormach, Inc

4009 Felland Rd Ste 116

Madison, WI

LOCATION:

+L1

CONTRACT:

User data 1

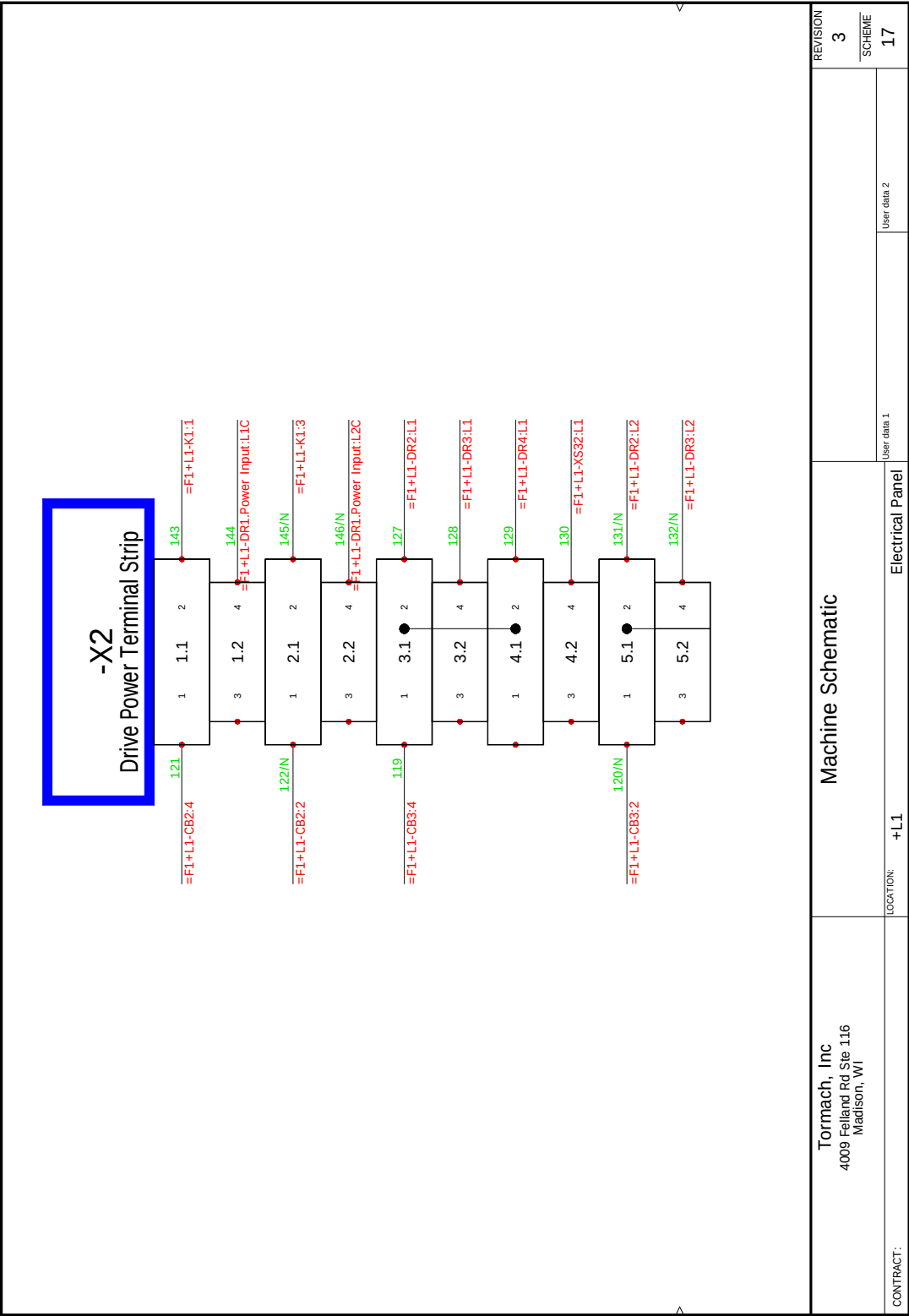
User data 2

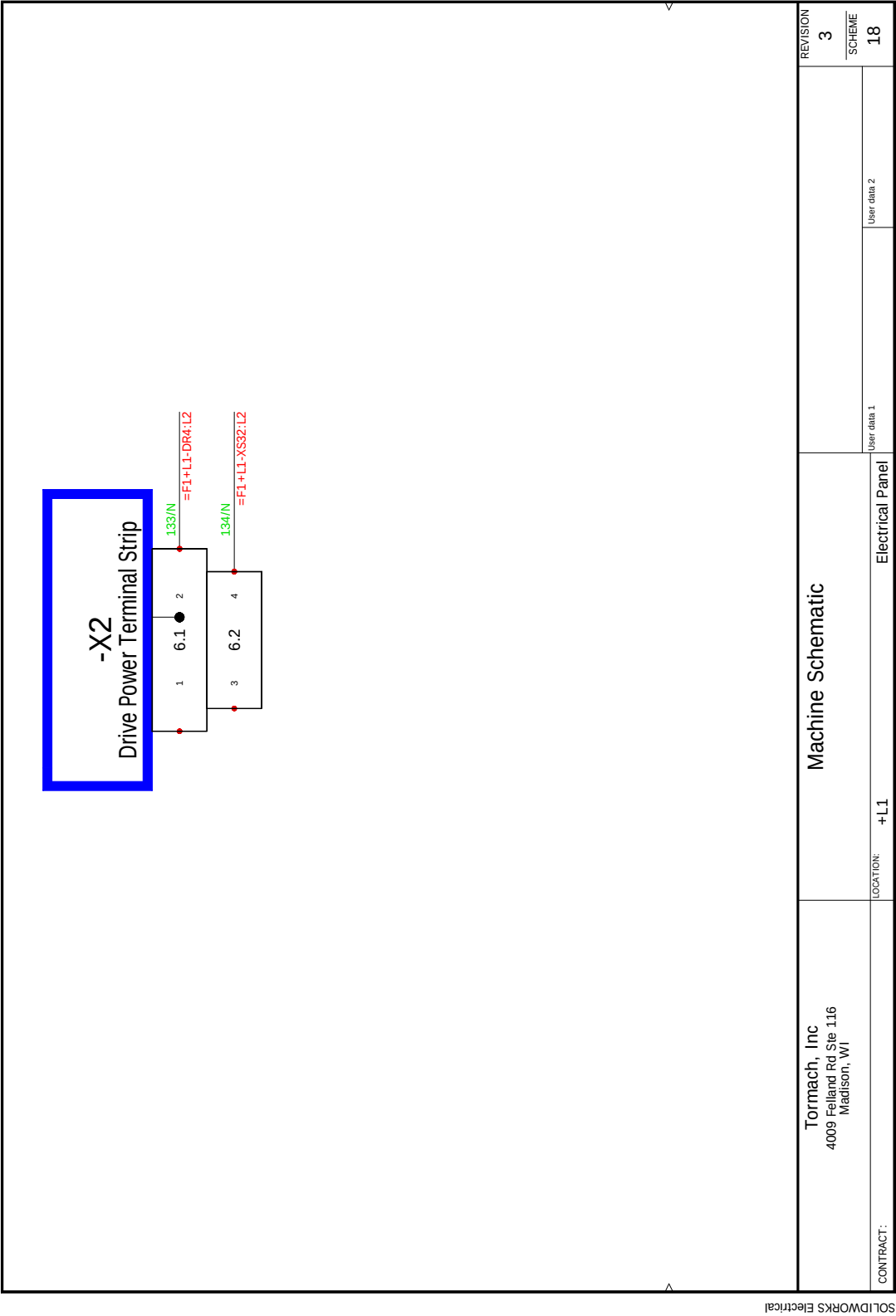
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12: ELECTRICAL SCHEMATICS
12.16 Terminal Strip- Drive Power (X2) (Pages 17-18)

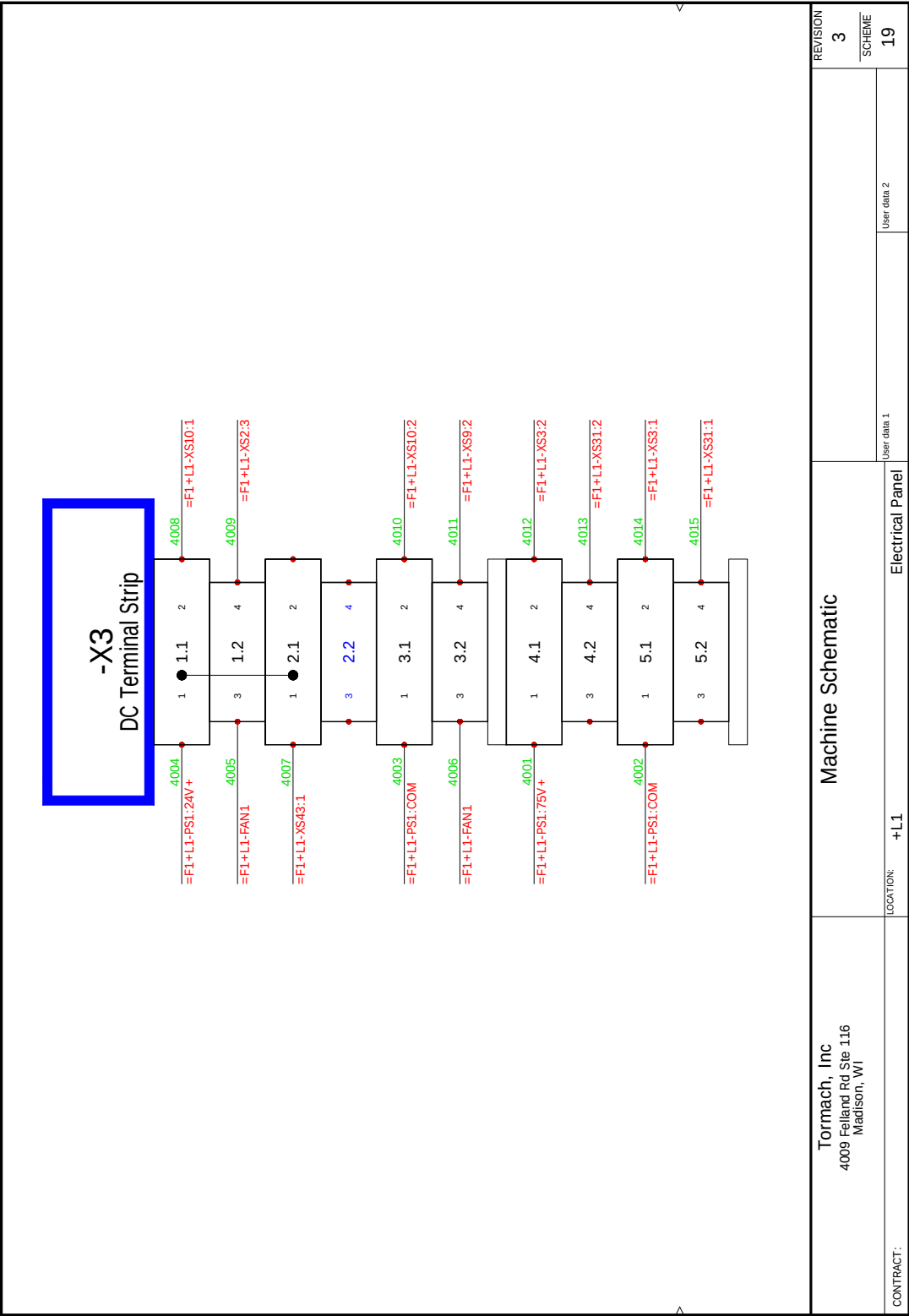
12.16 TERMINAL STRIP- DRIVE POWER (X2) (PAGES 17-18)



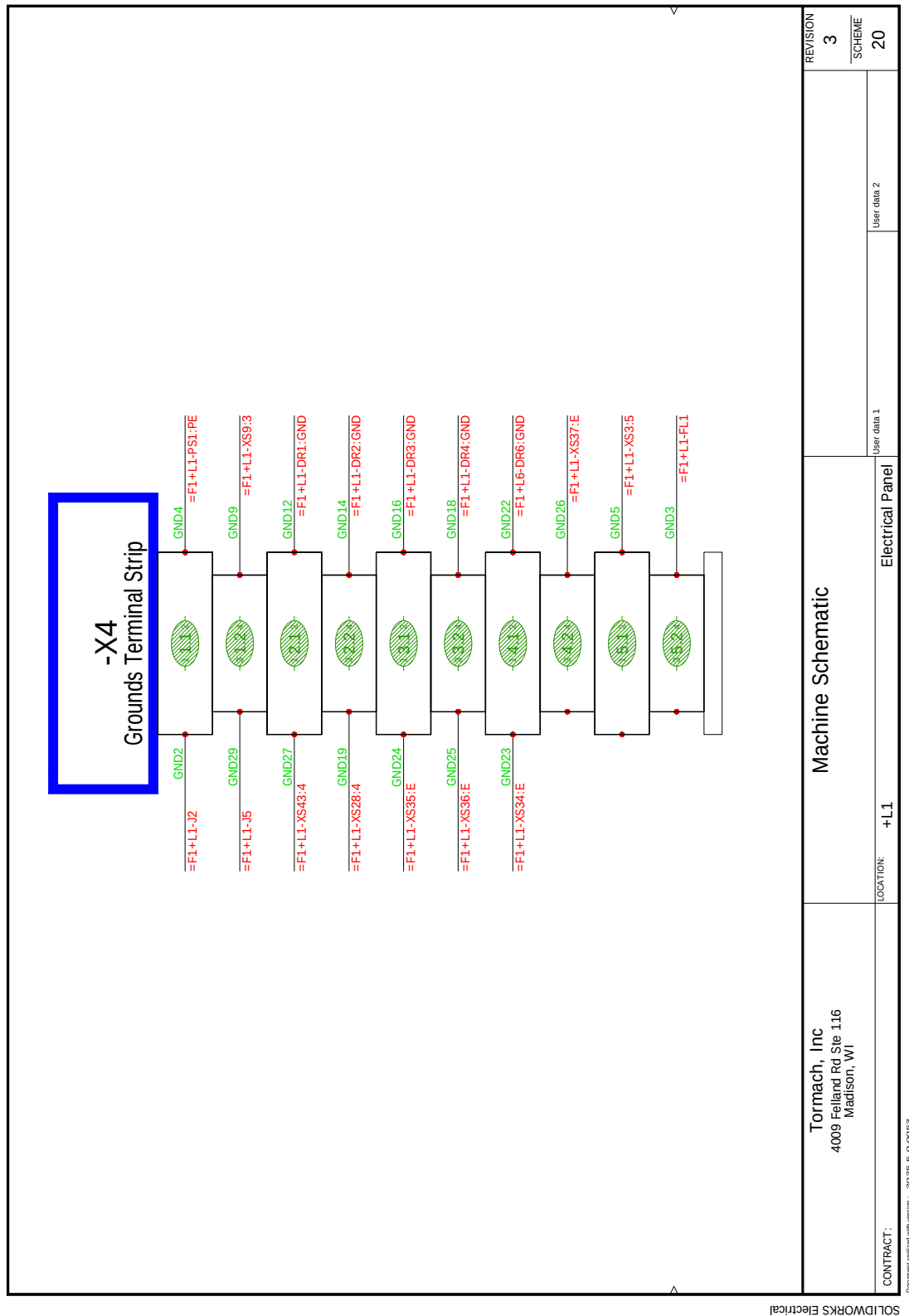


12: ELECTRICAL SCHEMATICS
12.17 Terminal Strip - DC (X3) (Page 19)

12.17 TERMINAL STRIP - DC (X3) (PAGE 19)



12.18 TERMINAL STRIP - GROUNDS (X4) (PAGE 20)



12: ELECTRICAL SCHEMATICS

12.19 Bill of Materials (Pages 21-22)

12.19 BILL OF MATERIALS (PAGES 21-22)

Reference	Mark	Location	Location description	Description	Quantity
52454	-J3	+L1	Electrical Panel	Jumper, Two Position, Female, 0.100IN Pitch	1
30235	-XS28	+L1	Electrical Panel	CPC Bulkhead, 7 Pin, Size 13	1
32636	-XS15	+L1	Electrical Panel	Terminal block (plug) 4 position Horizontal, Dagon	1
32638	-XS10, -XS11, -XS12, -XS13, -XS17, -XS18, -XS20, -XS21	+L1	Electrical Panel	Terminal block (plug) 2 position, Dagon	8
37754	-XS22	+L1	Electrical Panel	Term Block Plug, 4pos, 5.08mm	1
37756	-XS14	+L1	Electrical Panel	Terminal block (plug) 5 position, Dagon	1
50766	-XS9, -XS16, -XS19	+L1	Electrical Panel	Terminal block (plug) 3 position, Dagon	3
31120	-F1, -F2	+L1	Electrical Panel	Fuse, 3A, 250V, 5x20, Glass, Slow-Blow	2
51328	-DS1	+L2	Enclosure	Loading Door Switch	1
30464	-DS6C1	+L1	Electrical Panel	Main Disconnect Switch	1
37345	-CB1	+L1	Electrical Panel	Circuit Breaker, 2-Pole, 20A, 230/400VAC, D Curve, DIN Mount	1
37346	-CB2, -CB3	+L1	Electrical Panel	Circuit Breaker, 2-Pole, 10A, 230/400VAC, D Curve, DIN Mount	2
54472	-CB4	+L1	Electrical Panel	Circuit Breaker, 2-Pole, 6A, 230/400VAC, D Curve, DIN Mount	1
32954	-XS1	+L1	Electrical Panel	Industrial-Grade Straight-Blade Device NEMA 6-20 Male Plug, 250 VAC, 20 Amps	1
51194	-DR2, -DR3, -DR4	+L1	Electrical Panel	SV660N EtherCat AC Servo Drive, Size A	3
51337	-B1, -B2, -B3, -B4	+L1	Electrical Panel	Invoiance SV660N Battery Box	4
51348	-XS24, -XS25, -XS26, -XS27, -XS33	+L1	Electrical Panel	Invoiance STO Connector	5
51349	-XS32	+L1	Electrical Panel	CON SV660A 9P	1
54185	-DR1	+L1	Electrical Panel	SV660N EtherCat AC Servo Drive, Size C, 7.6A, STO Function	1
54294	-M1	+L3	Spindle Head	Servo Motor, 1kW, 220V, 6.5A, 3k RPM (7k Max), Oil Seal, R Sub-series	1
54297	-M4	+L4	Machine Frame	Servo Motor, 400W, 220V, 2.4A, 3k RPM (7k Max), Oil Seal and Brake, R Sub-series	1
54298	-M2, -M3	+L4	Machine Frame	Servo Motor, 400W, 220V, 2.4A, 3k RPM (7k Max), Oil Seal, R Sub-series	2
52306	-X2	+L3	Spindle Head	Five Port, Four Way, Two Position, 24VDC, Single Solenoid Valve, 1/8" (inlet/outlet), 1/8" (exhaust)	1
51800	-XS51	+L2	Enclosure	Connector, Plug, 2-pin Female JST, 2.5mm Pitch	1
51801	-XS50	+L2	Enclosure	Connector, Receptacle, 2-pin Male JST, 2.5mm Pitch	1
51857	-XS4, -XS5, -XS6, -XS7, -XS8	+L1	Electrical Panel	CONN RCPT HSG SPOS 2.54MM	5
51658	-XS40	+L1	Electrical Panel	Rectangular Connector, 2 Pin Male Vertical, Plug, White 0.185" (4.2mm)	1
51659	-XS30, -XS49	+L1 +L2	Electrical Panel; Enclosure	Rectangular Connector, 4 Pin Female Dual Row, Receptacle, White 0.165" (4.2mm)	2
51660	-XS48	+L1	Electrical Panel	Rectangular Connector, 4 Pin Male Dual Row, Plug, White 0.185" (4.2mm)	1
51661	-XS56	+L1	Electrical Panel	Rectangular Connector, 6 Pin Male Dual Row, Plug, White 0.185" (4.2mm)	1
51662	-XS58	+L3	Spindle Head	Rectangular Connector, 6 Pin Female Dual Row, Receptacle, White 0.165" (4.2mm)	1
51663	-XS31	+L1	Electrical Panel	Rectangular Connector, 2 Pin Female Vertical, Receptacle, White 0.185" (4.2mm)	1
Tormach, Inc 4009 Felland Rd Ste 116 Madison, WI					REVISION 3
Machine Schematic					PAGE 21
+L1					User data 1
Electrical Panel					User data 2

Document released with version : 2022.6, 6.0, 60053

Reference	Mark	Location	Location description	Description	Quantity
51664	XS57	+L3	Spindle Head	Rectangular Connector, 3 Pin Female Vertical, Receptacle, White 0.165" (4.2mm)	1
51665	XS55	+L1	Electrical Panel	Rectangular Connector, 3 Pin Male Vertical, Plug, White 0.165" (4.2mm)	1
52245	-B1, -B2, -B3, -B4	+L1	Electrical Panel	SV680N Encoder Battery Assembly	4
51599	XS37	+L1	Electrical Panel	Power Outlet (IEC 320, C13 Double Socket), Spade Terminals	1
51590	-XS34, -XS36	+L1	Electrical Panel	Power Outlet (IEC 320-2-2/F, C13 Single Socket), Spade Terminals	2
54188	XS35	+L1	Electrical Panel	Power Outlet (IEC 320, C13 Quadruple Socket), Spade Terminals	1
38579	GRI1	+L1	Electrical Panel	Cord Grip, PG9	1
32350	FL1	+L1	Electrical Panel	EMI Filter	1
37355	-XS23, -XS38	+L1	Electrical Panel	RJ45 Bulkhead Connector, 500mm long	2
37420	TS1	+L1	Electrical Panel	Thermal Switch (Pushbutton Reset)	1
37906	R1	+L1	Electrical Panel	Brake Resistor, 70 Ohm, 300 Watt w/ 20' leads	1
51239	-PB3, -PB4	+L2 +L3	Enclosure; Spindle Head	Pushbutton, 1NO1NC, White LED	2
51546	-XS52, -XS59, -PB3, -PB4	+L1 +L3 +L2	Electrical Panel; Spindle Head; Enclosure	Button Wiring Pigtail, 5-pin, For Tayen TM822 Buttons	4
51293	-XS39, -XS41	+L1	Electrical Panel	M12 Socket, Panel feed through, for rear mounting, A-coding, Crimp termination, 5 pin	2
51543	-XS2, -XS43	+L1	Electrical Panel	M12 Plug, Panel Mount, Female Pins, 4 Position, A Keying	2
51252	E1	+L1	Electrical Panel	Tormach Servo IO Breakout	1
51623	-E2, -E3, -E4, -E5	+L1	Electrical Panel	HD15 Male Pin to IDC 2x8 Socket Adapter	4
37526	FAN1	+L1	Electrical Panel	Fan, 120mm, 24V, 0.29A	1
51289	-XA-1, -XA-2, -XA-3, -XA-4, -XA-5	+L1	Electrical Panel	Terminal Block, GND, 24-10AWG, 4 position, Spring Type, Internally Jumpered	5
51290	-XS-1, -X1-1, -X2-1, -X2-2, -X1-2, -X2-3, -X2-4, -X2-5, -X1-3, -X1-4, -X2-4, -X2-5, -X1-5, -X3-5, -X1-6, -X2-6, -X1-7, -X1-8	+L1	Electrical Panel	Terminal Block, 24-10AWG, 4 position, Spring Type, Internally Jumpered	19
51291	-XS- , -X1- , -XA-	+L1	Electrical Panel	Terminal Block End Plain, JUT3-4/2-2 Series	4
54585	PS1	+L1	Electrical Panel	Power Supply, Dual Voltage 110-240 VAC, 24V & 75V, 150W, 6.5A, 50mmx215mm	1
39263	XS45	+L2	Enclosure	Circular Connector, Plug, 5 Pin Male, PVC Jacket, Solder	1
51163	XS46	+L2	Enclosure	Circular Connector, Plug, 5 Pin Female, PVC Sleeve, Solder	1
51538	-XS3, -XS44	+L1	Electrical Panel	Circular Connector, Front-Nut Mount Receptacle, 5 Pin Female, 20mm Cutout, Round, Solder	2
51598	XS42	+L1	Electrical Panel	Circular Connector, Front-Nut Mount Receptacle, Push-Pull, 10 Pin Female, 20mm Cutout, Round, Solder	1
37343	A1	+L1	Electrical Panel	Contact Relay, 3 position 230V 12A, 24v DC Coil, Screw Terminal	1

Machine Schematic

Electrical Panel

+ L1

User data 1

User data 2

REVISION

3

PAGE

22

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