OPERATOR'S MANUAL

Original Instructions

Version 1223A

TORMACH® 770M

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To the Reader

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ABOUT THIS DOCUMENT

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

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 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)

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

ADDITIONAL INFORMATION

For additional technical information and support videos, see tormach.com/support.

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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.

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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 **22**
1.2 Machine Standards **22**
1.3 Safety Overview **22**
1.4 Machine Safety **24**
1.5 Noise Exposure **26**

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" (above)), 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*

1.3 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

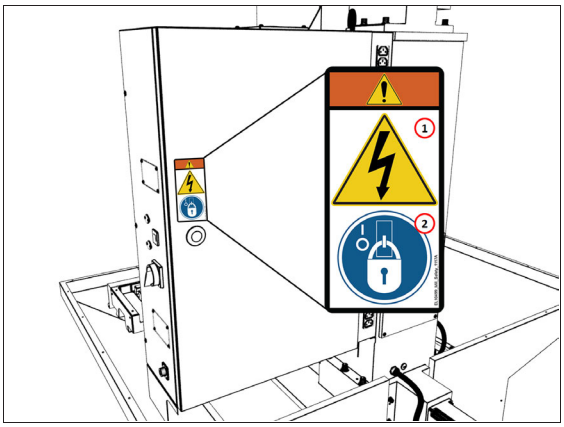

Figure 1-1: Example of a safety decal on the electrical cabinet door.

1. **WARNING! Electrocution 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

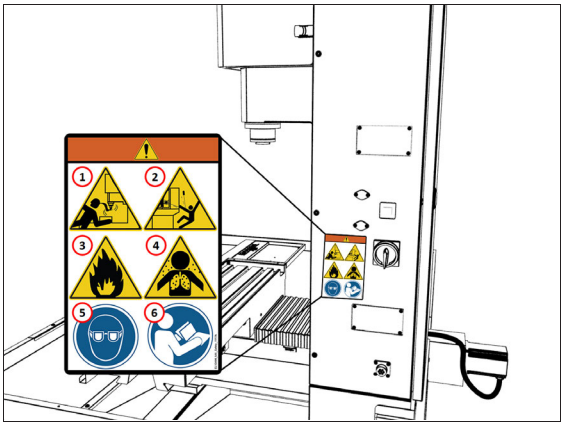

Figure 1-2: Example of a safety decal next to the Main Disconnect.

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 787+.
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

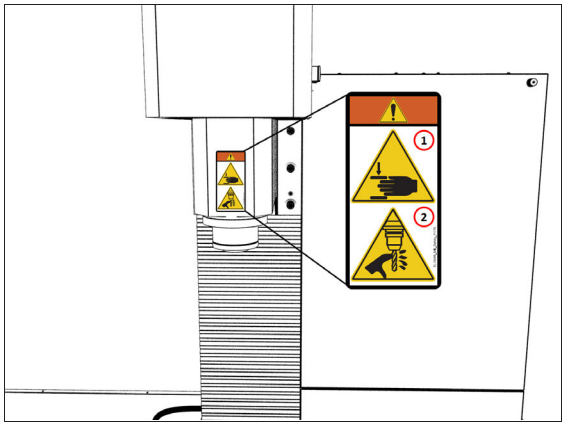

Figure 1-3: Example of a safety decal on the spindle nose.

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.

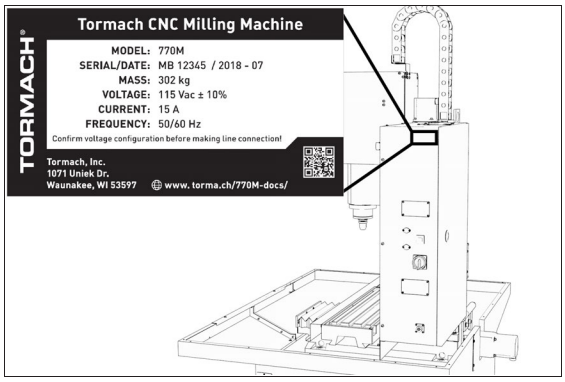

Figure 1-4: Example of the serial number plate on the side of the electrical cabinet.

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 **24**
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" (on the next page).
- 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.
- 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 22).
- 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 35).
- 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.

1.5 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.

DRMACH

ABOUT YOUR MACHINE

IN THIS SECTION, YOU'LL LEARN:

- About this machine's specifications.

CONTENTS

2.1 Performance Expectations **30**

2.2 Machine Specifications **31**

2.1 PERFORMANCE EXPECTATIONS

Each machine ships with a Certificate of Inspection, which details quality assurance measurements performed by members of our quality assurance team prior to shipping.

2.1.1 Cutting Performance

This machine is capable of cutting a wide variety of materials (for information, see "Intended Use" (page 22)) at or near their recommended feeds and speeds. Make sure that your workpiece is held as rigidly as possible and use the most rigid tooling available for roughing cuts. Verify that the programmed operations do not exceed the available spindle power.

- **Spindle Speed Range**
  Two speed ranges are available:
  - **Low** 175 rpm to 3250 rpm
  - **High** 525 rpm to 10,000 rpm
- **Spindle Power Rating** 1.5 hp (1.1 kW)
- **Maximum Feed Rate**
  - **X- and Y-Axis** 135 IPM (3.43 m/min)
  - **Z-Axis** 110 IPM (2.7 m/min)

2.1.2 Resolution and Accuracy

Accuracy is heavily influenced by the techniques that the machinist uses. A skilled machinist can deliver accuracy that exceeds the specified accuracy from the manufacturer; an inexperienced machinist may have difficulty delivering the specified accuracy. We can't predict operator accuracy, but the specified accuracy is an important reference point.

- **Resolution** 0.0001"

> **Note:** The resolution of motion is the minimum discrete positional move.

- **Ball Screw Positional Accuracy** ≤ 0.0006 in./ft
- **Positional Accuracy** ≤ 0.0013 in./ft

> **Note:** The positional accuracy includes additional contributing factors (like compressibility of bearings, ball screw windup, and friction).

2.2 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	14.25" (362 mm)
Spindle Centerline to Machine Column	8.6" (218 mm)
Spindle	
Spindle Power	1.5 hp (1.1 kW)
Spindle Maximum Speed	10,000 rpm
Transmission	Poly-V Belt
Spindle Taper	R8
Thread Machining	Tension/Compression, Auto-Reversing, Thread Mill
Maximum Feed Rate	
X- and Y-Axis	135 IPM (3.43 m/min)
Z-Axis	110 IPM (2.7 m/min)
Axis Motor	Stepper Driven
Power	
Primary Power Required	Single-Phase 115 Vac, 50/60 Hz
Recommended Circuit Amperage	Dedicated 15 A breaker
Table	
Table Size	26" × 8" (660 mm × 203 mm)
T-Slot Size	5/8" (15.9 mm) (three slots)
Maximum Weight on Table	400 lb (181 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)

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Specifications subject to change without notice.

DRMACH

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 **35**

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 115 Vac, 50/60 Hz
  - **Recommended Circuit Amperage** Dedicated 15 A breaker

> **Note:** For more information, see "Electrical and Power Requirements" (on the next page).

- 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.

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

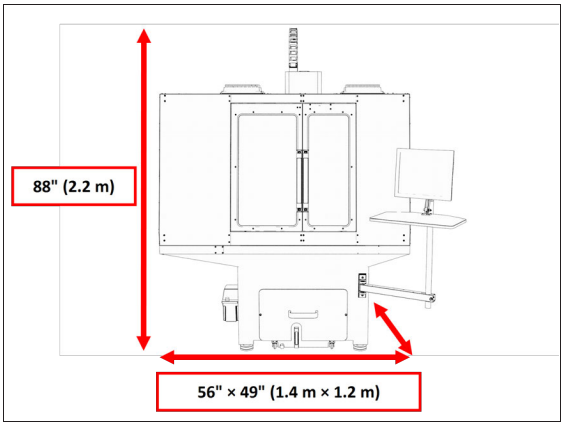

Figure 3-1: Dimensions of the machine itself, as viewed from the front.

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

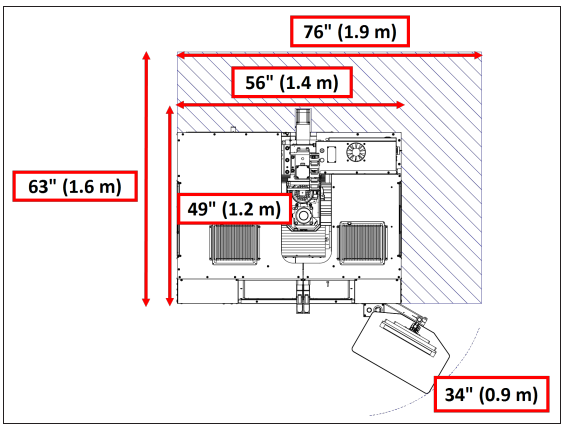

Figure 3-2: Dimensions of the machine and it's required added space, as viewed from above.

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 Controller Arm, as shown in the following image.

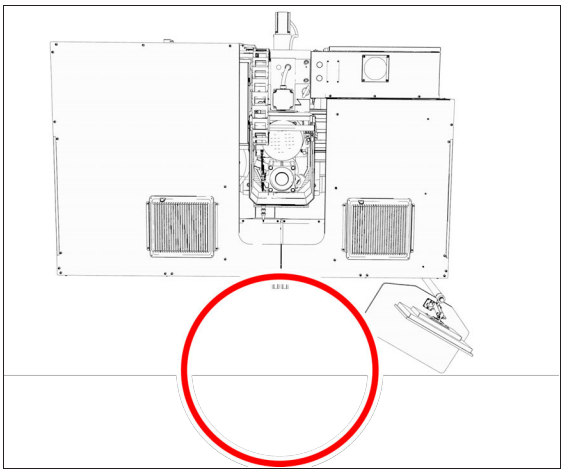

Figure 3-3: Example of the typical operator workstation.

For information on the machine controls, go to "System Basics" (page 109).

3.2 ELECTRICAL AND POWER REQUIREMENTS

You must verify that the site conforms to the following electrical and power requirements. If it doesn't, you may consider other options: go to "Options for Non-Conforming Sites" (below).

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 115 Vac, 50/60 Hz
- **Recommended Circuit Amperage** Dedicated 15 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 5-15P plug, designed for use with a NEMA 5-15R receptacle.

3.2.3 Options for Non-Conforming Sites

For sites that don't conform to the specified "Electrical and Power Requirements" (above), you may consider the following. You must consult with an electrician to determine the suitability for your site.

- **Step-Down Transformer** Used at sites where 115 Vac service is not possible. You must make sure that the step-down transformer has sufficient capacity to supply the machine, accessories, and any 115 Vac auxiliary equipment. We recommend the Step-Up/Step-Down Transformer (PN 32009).

DRMACH

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, a Power Drawbar, 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.

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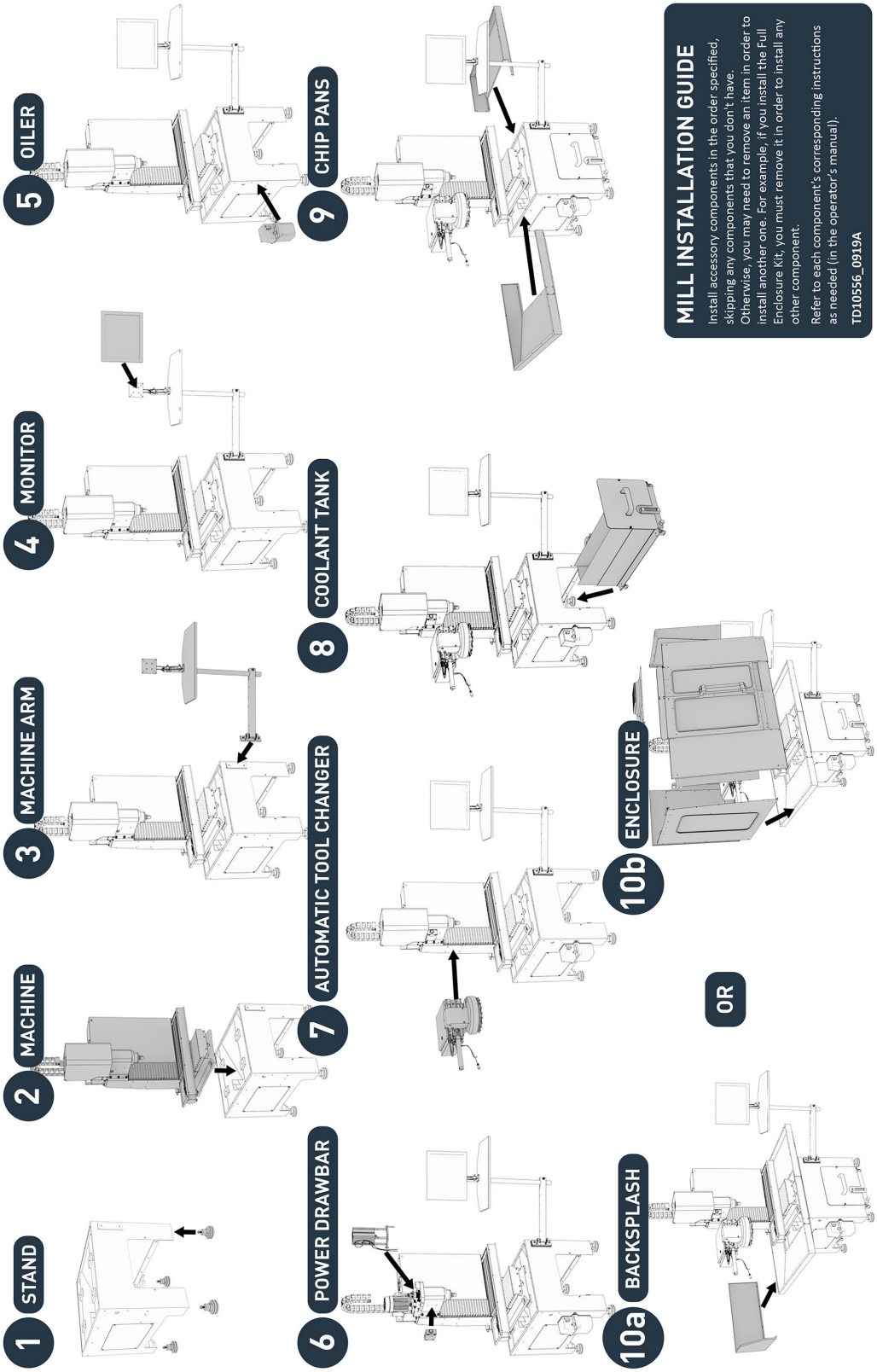
4.9 Set Up the PathPilot Controller **107**

4: INSTALLATION

4.1 VISUAL INSTALLATION GUIDE



4.2 BEFORE YOU BEGIN

1. Read the packing list to see 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.

2. 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.
   - 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.

4.3 INSTALLATION TOOLS AND ITEMS

Before uncrating and installing your machine, collect the following tools and items.

4.3.1 Required

- 4 mm hex wrench (included in tool bag)
- 1000-lb capacity engine hoist
- Assistant to help you
- Combination wrench set
- Consumables, like:
  - Anti-seize
  - Air tool oil
  - Machine way oil
- Digital multimeter
- Hammer
- Level (2 ft)
- Lifting Bar Kit (PN 31446)
- Pallet jack
- Phillips screwdriver (included in tool bag)
- Pry bar
- Reciprocating saw (or similar) to break down the pallet
- Safety eyewear that meets ANSI Z87+
- Shears or knife
- Socket set
- Step ladder
- Snips
- Work gloves

4.3.2 Optional

- Moving Kit (PN 31333)

4.4 MOVE THE PALLET

Tools and Items Required

- Pallet jack

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).

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.

4.5 ASSEMBLE THE MACHINE STAND

Tools and Items Required

- Work gloves
- Safety eyewear that meets ANSI Z87+
- Hammer
- Pry bar
- Snips

> ⚠ **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. 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.
5. Find the accessory box inside the Machine Stand, which contains the feet for the Machine Stand. Set it aside for later installation.
6. Remove the shipping bolts on the coolant tank, and then move it out of the Machine Stand and off of the pallet.
7. In the coolant tank, find four casters and their hardware.
8. Attach each of the four casters to the bottom of the coolant tank with four M6 × 12 mm socket head cap screws, spring washers, and flat washers. Then, set the coolant tank aside for later installation.
9. Remove the four nuts securing the Machine Stand to the pallet with a 17 mm wrench. Discard the four nuts.
10. To install the Machine Stand's feet, you must first lay it on its front surface. Put a large piece of cardboard (or similar) on the floor to protect the Machine Stand.

> ⚠ **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.

11. Lift the Machine Stand off the pallet, and set it down on the cardboard that you put on the floor in Step 10.

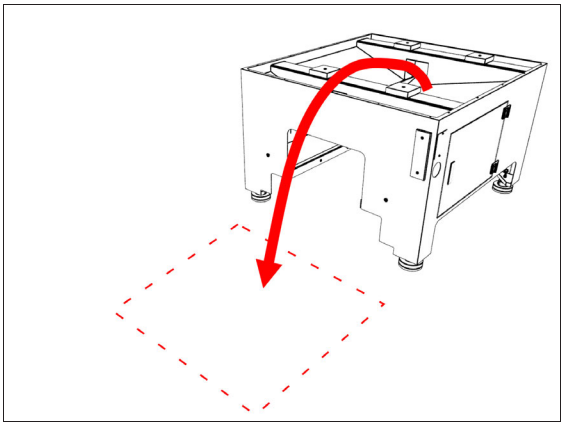


Figure 4-1: Cardboard on the floor to set the Machine Stand on.

12. Open the accessory box that you set aside in Step 5, and then identify the hardware inside (which is used to assemble the feet for the Machine Stand).

> **Note:** There are four large spacers in the accessory box that are used to assemble the feet for a 770M/MX mill. If you're assembling the feet for an 1100M/MX mill, discard the spacers.

13. Identify the foot pad from the accessory box, and unscrew the foot adjuster as shown in the following image. Then, apply Anti-Seize to both components, and reassemble the foot pad.

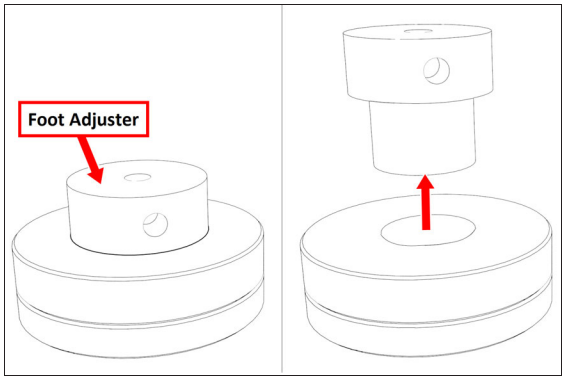


Figure 4-2: Disassembling the foot pad to apply Anti-Seize on each component.

14. Put the foot adjuster back into the base of the foot pad, but don't tighten it completely. Leave two threads visible so that you can adjust the stand up or down later in this procedure.
15. Put the threaded end of one M12 stud into each foot pad.

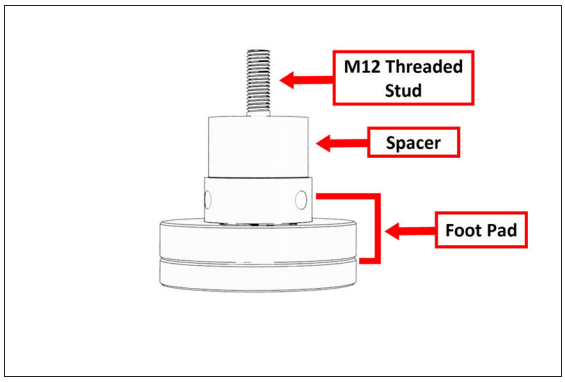


Figure 4-3: Machine Stand foot assembly.

16. Put one spacer on the M12 stud in each foot pad.
17. Put one foot assembly into the corner of the Machine Stand, and then use one M12 washer and one M12 nut to secure the foot assembly in place by hand.

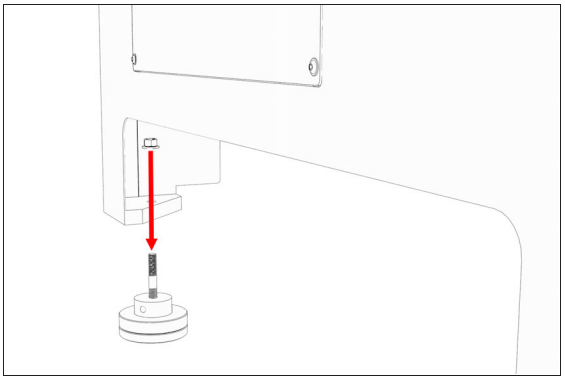


Figure 4-4: One foot assembly aligned with the corner of the Machine Stand.

> **Note:** Only attach the feet so that they're finger-tight. You'll tighten them completely after you've leveled the stand.

Repeat this step for the remaining three foot assemblies.

> **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.

18. Tilt the Machine Stand off the floor and onto its feet.

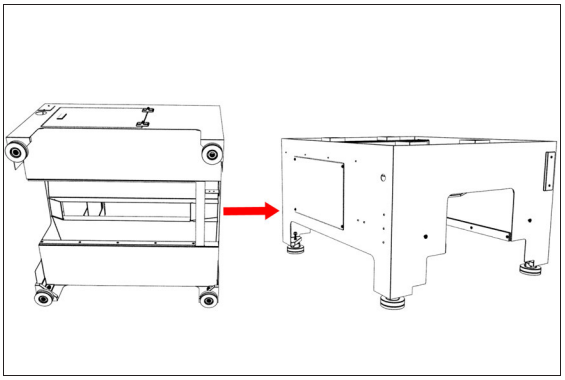


Figure 4-5: The Machine Stand moved onto its newly installed feet.

19. Level the feet as needed with the provided 3/8 in. (or 10 mm) adjustment bar.
20. Securely tighten all four of the feet to the Machine Stand with a 19 mm wrench.

4.6 UNPACK THE MACHINE 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. Remove and discard the plastic wrap from the machine.
5. 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.
6. Cut and remove the shipping straps securing the tool bag and Emergency Stop box to the pallet.

The tool bag contains the following items:

- 770M Cable Kit
- Double open-end wrenches: 13 mm/16 mm, 18 mm/21 mm
- Drawbar
- Drawbar thrust washer
- Electrical cabinet key
- Hex wrench set: 3 mm, 4 mm, 5 mm, 6 mm, 8 mm, and 10 mm
- Phillips screwdriver
- Tormach Tooling System (TTS) collet

> **Note:** There are two spare fuses included with the machine (5A, 5 × 20 mm, glass slow-blow), which are taped to the inside of the electrical cabinet.

7. Remove all packing materials from the spindle head.

4.7 INSTALL CORE COMPONENTS

After moving and unpacking the machine crate, you must install the core components of the system. Complete the following steps in the order listed:

4.7.1 Install the Y-Axis Motor **42**
4.7.2 Lift and Move the Machine **43**
4.7.3 Install the Controller **46**
4.7.4 Install the Oiler **50**
4.7.5 Verify the Installation **51**

4.7.1 Install the Y-Axis Motor

> ***NOTICE!*** The axis motor wires can't support the weight of the motor. To avoid property damage, carefully move the motors.

1. Remove the screws securing the motor mount cover with a 3 mm hex wrench. Set the screws and cover aside.

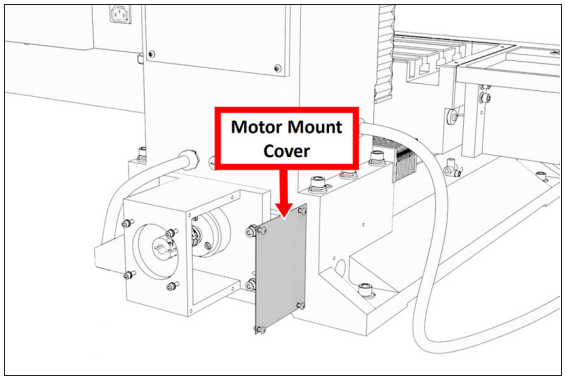


Figure 4-6: Motor mount cover.

2. Loosen the two motor shaft coupling screws with a 3 mm hex wrench.

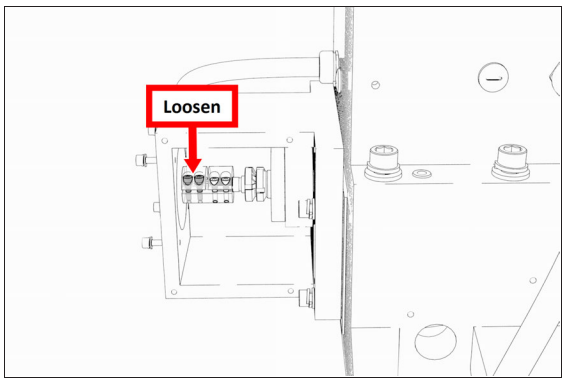


Figure 4-7: Two motor shaft coupling screws to loosen.

3. Remove the four M5 cap head screws, lock washers, and washers from the motor mount with a 4 mm hex wrench. Set all aside.

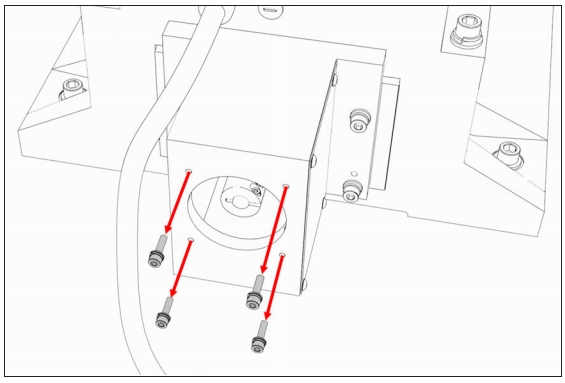


Figure 4-8: Motor mounting hardware removed from the motor mount.

4. Remove any paint bleed from the face and bore of the motor mount with a mild abrasive.
5. Remove the Y-axis motor from the pallet and/or the machine, and discard the shipping materials.
6. Mount the Y-axis motor onto the Y-axis motor mount with the four M5 cap head screws, lock washers, and washers that you removed in Step 3. Verify that the motor and motor mount faces are flush.

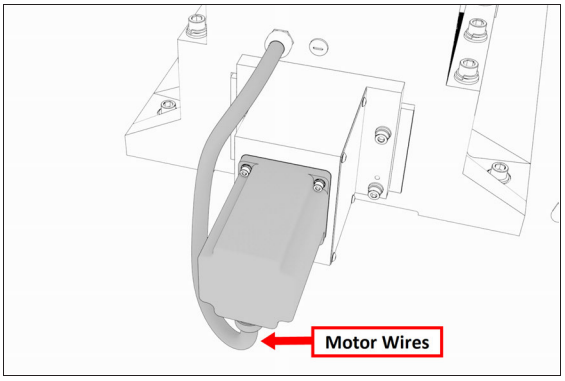


Figure 4-9: Flex conduit on the Y-axis motor facing the floor.

7. Securely tighten all four M5 cap head screws.
8. Position the coupling so that it's centered between the motor shaft and machined end of the ball screw, and then tighten the cap screws on the coupling.
9. Replace the motor mount cover that you removed in Step 1.

4.7.2 Lift and Move the Machine

For safety and security, use the Lifting Bar Kit (PN 31446) to lift the machine from above.

Note: It's possible to lift the machine from below with two steel bars — one in either 7/8-in. (22 mm) diameter hole on the machine base. The bars must be made of steel, at least 32 in. (813 mm) long, and must not be hollow. You must make sure that the machine is properly secured before lifting so that it does not roll or shift in the process. For maximum safety and security, we strongly recommend that you lift the machine from above, as outlined in this section.

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. Remove any excess shipping grease on the machine with a mild degreaser (like WD40® or similar).

3. To allow room to position the engine hoist, you must first trim the pallet: cut the machine's pallet along the sides of the machine's base casting with a reciprocating saw (or similar).
4. Remove the nuts from the four studs that hold the machine to the pallet with a 19 mm wrench. Discard the nuts.

> ⚠ **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.

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

Required Tools **44**
Before You Begin **44**
Assemble the Lifting Bar Kit **44**
Connect the Machine for Lifting **44**
Lift the Machine **45**

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.

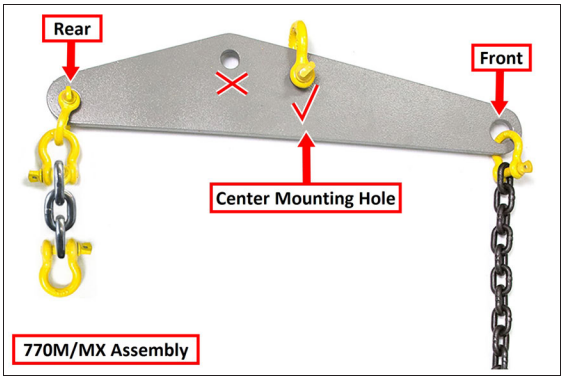


Figure 4-10: Center mounting hole on the Lifting Bar Kit.

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 4-11: 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 4-12: 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.

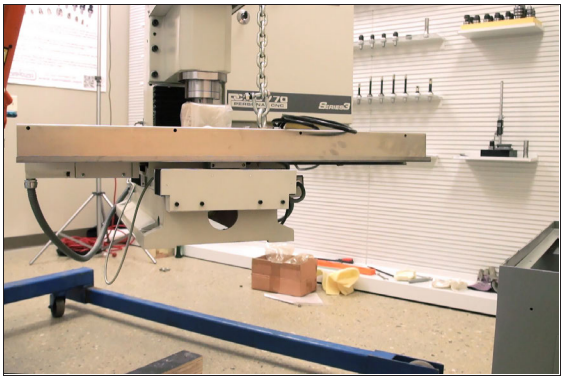


Figure 4-13: Machine lifted parallel to the floor.

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.
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 4-14: 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.

4.7.3 Install the Controller

Depending on your machine configuration, do one of the following:

- **If You Have a Controller Arm** Go to "Install the Controller Arm" (below).
- **If you have a PathPilot Operator Console** Go to "Set Up the PathPilot Operator Console" (page 49).

> **Note:** The PathPilot operator console is mounted to the enclosure, but we don't recommend completely installing it (or the enclosure) until after you've installed all other major accessories.

Install the Controller Arm

Tools and Items Required

- 4 mm hex wrench
- 6 mm hex wrench
- 8 mm hex wrench
- 17 mm hex wrench
- 17 mm socket wrench
- 21 mm wrench
- Dead-blow hammer (or similar)
- Phillips screwdriver
- Pry bar

> **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. Open the Controller Arm crate with a pry bar.
3. Find the mounting pad on the machine stand.

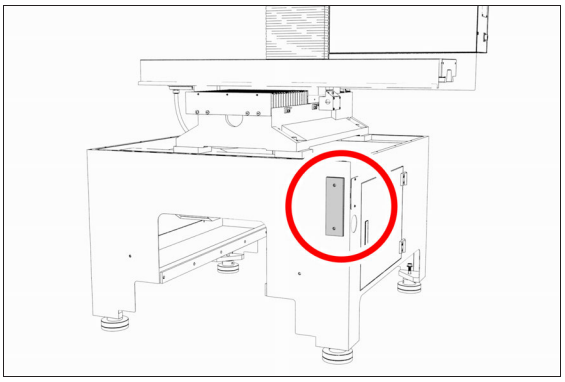


Figure 4-15: Controller Arm mounting pad.

4. Secure the square tube arm to the machine stand with two M8 socket head cap screws, two M8 flat washers, two M8 lock washers, and a 6 mm hex wrench. Verify that the white nylon washer is located toward the bottom of the mounting pad.

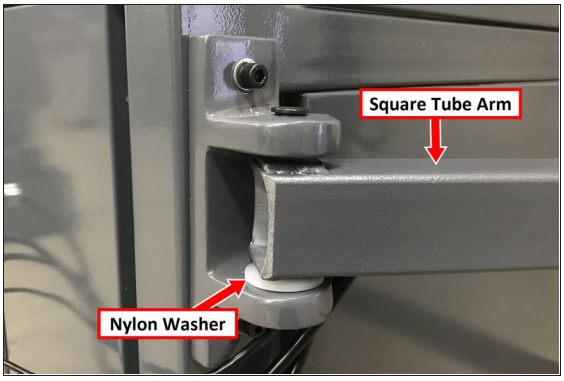


Figure 4-16: White nylon washer on the square tube arm.

5. Put the monitor post into the square tube arm. Verify that the monitor bracket is toward the top, and that the threaded holes face the holes in the square tube arm.
6. Tighten the cross bolt on the square tube arm with a 17 mm socket wrench and a 17 mm hex wrench.
7. With a 21 mm wrench, remove the monitor bracket from the Controller Arm, and rotate it so that the largest mounting plate is facing up.

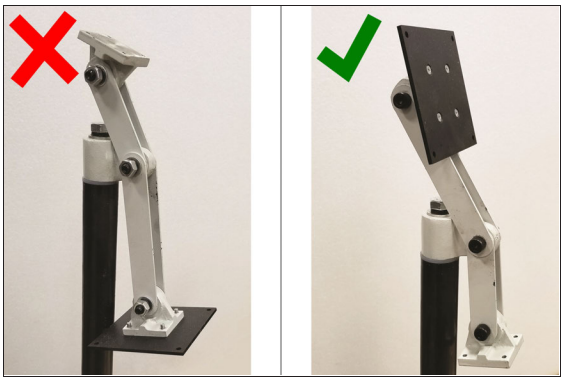


Figure 4-17: Incorrect and correct orientations of the monitor bracket on the Controller Arm.

> **Note:** The largest mounting plate is for the monitor, and the smallest mounting plate is for the keyboard tray.

8. Tighten the three pivot bolts on the monitor bracket with an 8 mm hex wrench and a 16 mm wrench.

Figure 4-18: Tightening the monitor bracket in place.

> **Tip!** This makes it easier to install the monitor, which you'll do later in this installation procedure.

9. Tap the end plug into the square tube arm with a dead-blow hammer (or similar).
10. Secure the keyboard table to the monitor bracket with four M5 socket head cap screws, four M5 flat washers, four M5 split lock washers, and a 4 mm hex wrench.
11. Attach four wire tie mounts to the monitor post with four 4 mm flat head machine screws and a Phillips screwdriver.

Install the Monitor

1. Remove the four screws on the existing monitor mounting plate with a Phillips screwdriver. Set aside the screws, and discard the existing monitor mounting plate.

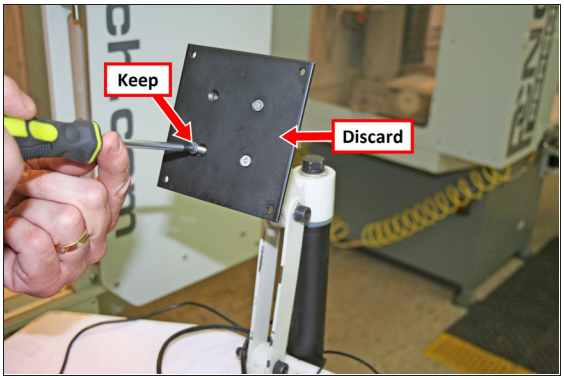


Figure 4-19: Existing monitor mounting plate.

2. Mount the VESA mount plate to the Controller Arm with the four screws that you set aside in Step 1.
3. Align the monitor with the VESA mount plate.
4. Attach the top of the monitor to the VESA mount plate with a Phillips screwdriver and two M4 × 10 mm machine screws.
5. Attach the bottom of the monitor to the VESA mount plate with a Phillips screwdriver and two M4 × 10 mm thread-forming screws.

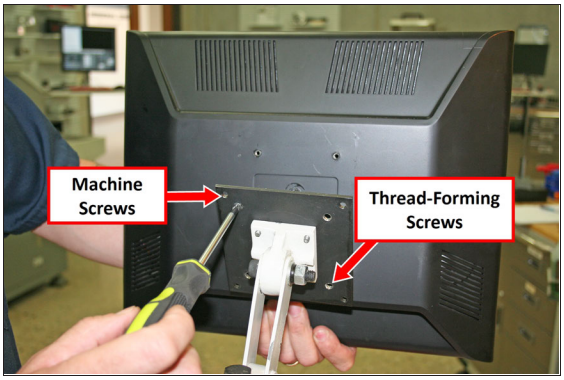


Figure 4-20: Monitor installed on the VESA mount plate.

Make Monitor Connections

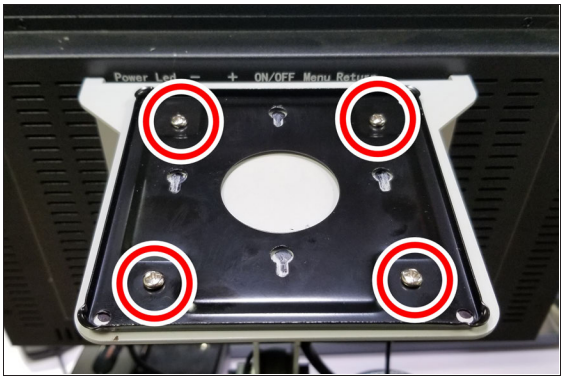
1. Connect the monitor's cables.
2. Route all of the cables' loose ends down the Controller Arm.
3. Secure the cables to the wire tie mounts that you installed on the round monitor post with four 4 in. cable ties.
4. Route the loose ends of all the cables through the slots in the square tube arm.
5. Route the loose end of the power cable to the back of the electrical cabinet, and connect it to any of the **Accessory** power outlets on the side of the electrical cabinet.

Install the PathPilot Controller

The PathPilot controller attaches to the top of the PathPilot Controller VESA Mount and behind the monitor.

1. Put four standoffs into the controller and tighten them by hand.

2. Find the four M4 screws and the VESA plate included with the controller. Then, mount the VESA plate to the PathPilot Controller VESA Mount (PN 50382). Make sure to put it flat side down with the keyholes toward the monitor.



3. Attach the controller to its mount by sliding the standoffs through the key slots.

4. Connect all USB accessories to the controller:
   - Jog Shuttle (PN 30616) (Optional)
   - Keyboard
   - Mouse
   - Monitor
5. Connect the monitor's video cable to the controller.
6. Route the loose end of the video cable toward the monitor, and then connect it to the monitor.
7. Connect the power supply to the controller.
8. Connect the loose end of the power supply to one of the **Controller/Monitor** cables provided.
9. Route the power cables to the electrical cabinet.
10. Connect the power supply for the controller to any of the **Accessory** power outlets on the back of the electrical cabinet.
11. Find the Ethernet cable, and then connect it to the **Controller Communications** outlet on the side of the electrical cabinet.
12. Route the loose end of the Ethernet cable toward the controller and then connect it.
13. Secure the wire loom, Ethernet cable, and power supply cables to the Controller Arm with six wire tie mounts and six cable ties.

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. Find the following items, which are provided with the PathPilot operator console:
   - *(Optional)*Automatic Tool Changer (ATC) USB cable

     > **Note:** If you're not installing an ATC, you don't need to use this cable.

   - Ethernet cable
   - Jog Pendant (PN 50363)
   - Machine controller
   - Operator box extension cable
   - WiFi dongle
2. Temporarily put the machine controller near the machine (on a workbench, or similar).
3. Identify the machine's operator box, and remove the Emergency Stop cable from it.
4. Connect the operator box extension cable to the Emergency Stop cable.
5. Find the PathPilot controller's power cable and power supply (provided in the machine owner's kit).

   > **Note:** The controller's power supply is designed to work with either 115 Vac or 230 Vac.

6. Connect the power, Ethernet cable, emergency stop extension cable, ATC USB cable, WiFi dongle, and the jog pendant cable to the controller as shown in the following image.

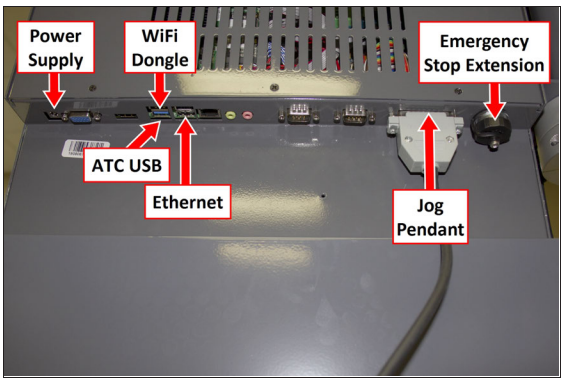


Figure 4-21: Controller connections.

7. Connect the Ethernet cable to the Controller Communications port on the side of the electrical cabinet.
8. Lay the control console down on the work surface to prevent tipping. Prop up the console to avoid pinching the cables.

4.7.4 Install the Oiler

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

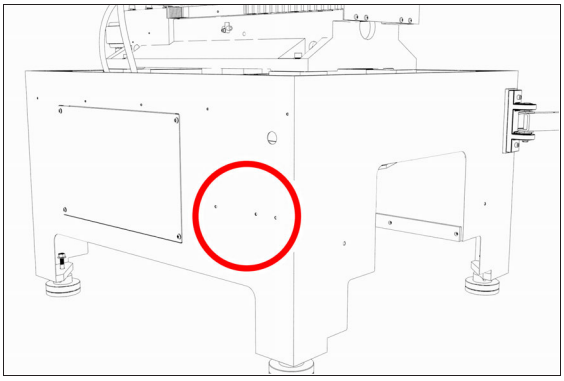


Figure 4-22: Oiler installation location on the left side of the machine stand.

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

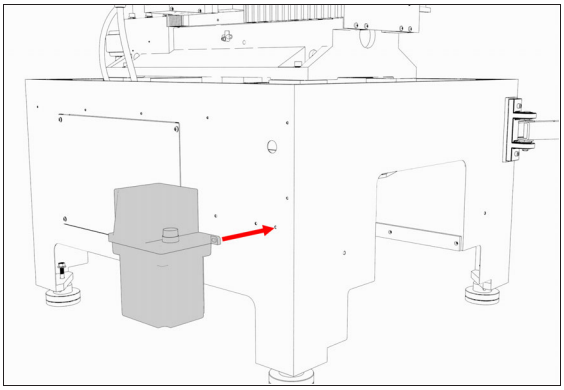


Figure 4-23: Automatic oiler installation on the machine stand.

3. Depending on your oiler type, do one of the following:
   - If you have an automatic oiler (optional), go to "Make Automatic Oiler Connections" (below).
   - If you have a manual oiler, go to "Make Manual Oiler Connections" (below).

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.
5. 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" (on the next page).

> **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 55).

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:
   - Evert 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 installation before you use the machine for the first time. Go to "Verify the Installation" (on the next page).

4.7.5 Verify the Installation

After installing the base machine, you must verify the installation. Complete the following steps in the order listed:

Power On the Machine 51
Power Off the Machine 52
Verify Limit Switch Function 53
Verify Axes Function 53
Verify Spindle Function 54

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 115 Vac, 50/60 Hz
   - **Recommended Circuit Amperage** Dedicated 15 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 (if present).

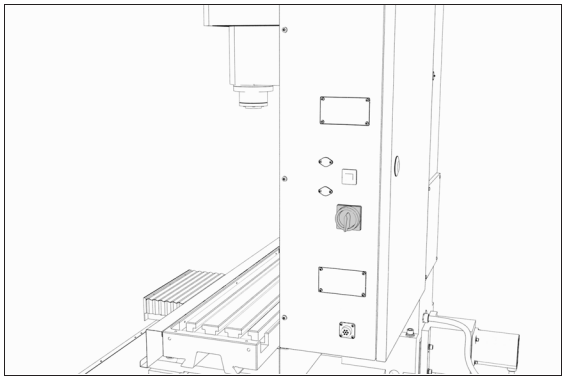


Figure 4-24: The Main Disconnect switch on the side of the machine's electrical cabinet.

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

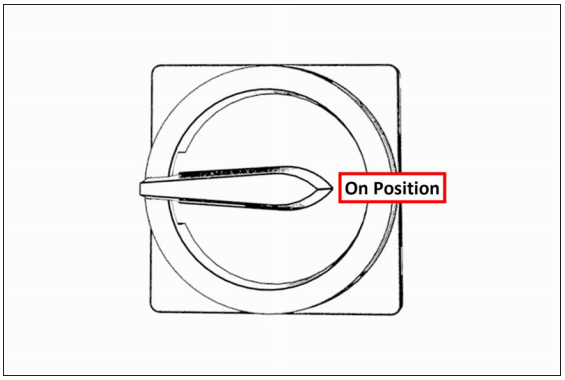


Figure 4-25: Example of the Main Disconnect switch in the On position.

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. Push the Power button on the monitor, if it's not already powered on.
7. 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.

8. Depending on which monitor you have, do one of the following:
   a. **Standard Monitor** Go to the next step.
   b. **Touch Screen Monitor** You must first make sure that the monitor is configured and calibrated. From the PathPilot interface, in the **MDI Line** DRO field, type `ADMIN TOUCHSCREEN`. Then, select the **Enter** key, and follow the on-screen instructions.

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9. Rotate the Emergency Stop button on the operator box one-quarter turn clockwise to release it.

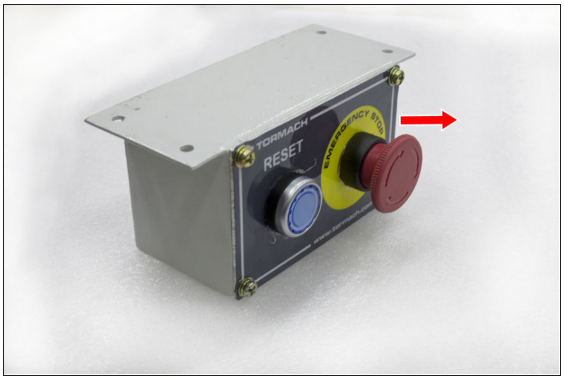


Figure 4-26: The Emergency Stop button on the operator box.

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

Figure 4-27: The Reset button on the operator box.

The axis drives are now powered on.

11. Verify that the blue Reset LED on the operator box 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 4-28: Machine OK light on the Status tab.

12. Select **Reset**.

Figure 4-29: Reset button.

Power Off the Machine

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

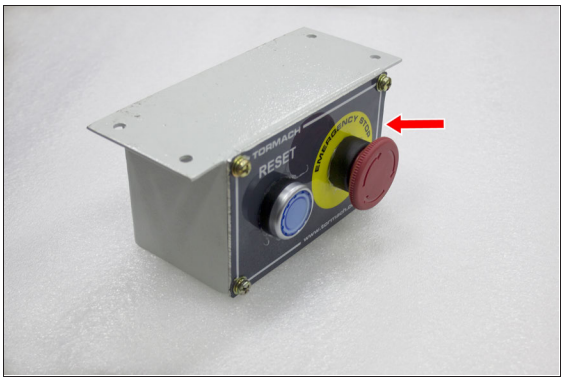


Figure 4-30: Example of the Emergency Stop button locked in the disabled position.

With the Emergency Stop button in the disabled position all motion and spindle function stops, and the Reset button is disabled. On the operator box, 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**.

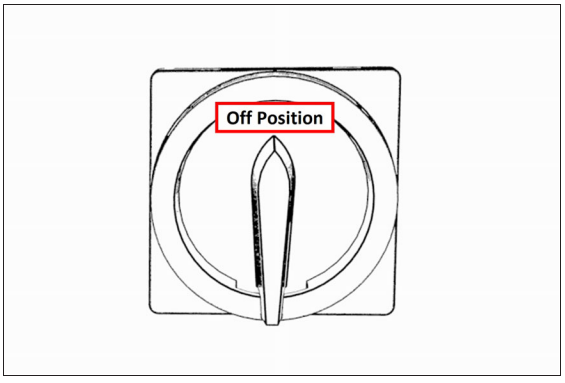


Figure 4-31: Example of the Main Disconnect switch in the Off position.

Mains power is disconnected from the machine.

Verify Limit Switch Function

You must confirm that the limit switches correctly operate.

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 Reset button.
2. From the PathPilot interface, on the **Status** tab, identify the **X Limit**, **Y Limit**, and **Z Limit** lights.

Figure 4-32: X Limit, Y Limit, and Z Limit lights on the Status tab.

3. On the machine, identify the **X**, **Y**, and **Z** limit switches.

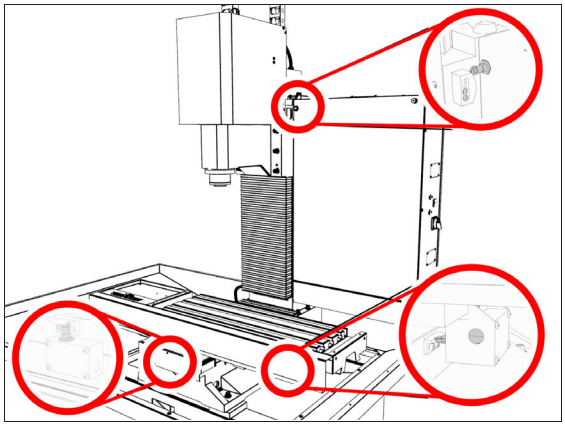


Figure 4-33: Machine limit switches.

4. One at a time, press the **X**, **Y**, and **Z** limit switches. From the PathPilot interface, on the **Status** tab, the corresponding **X Limit**, **Y Limit**, and **Z Limit** lights come on.
5. From the PathPilot interface, select **Reset**.

Verify Axes Function

You must confirm that the axes correctly operate.

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

Figure 4-34: Ref Z, Ref X, and Ref Y buttons.

The machine moves to the reference position.

5. 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+).

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

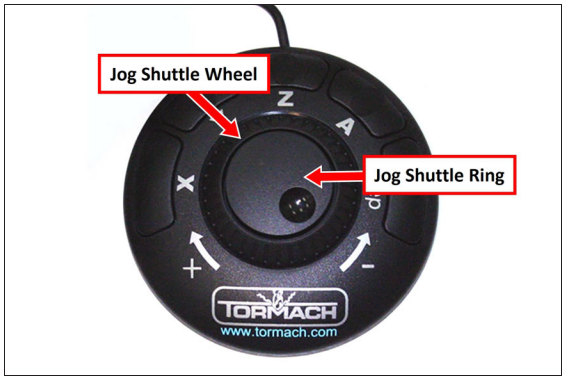


Figure 4-35: Functions on the optional Jog Shuttle.

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

Figure 4-36: 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.

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.

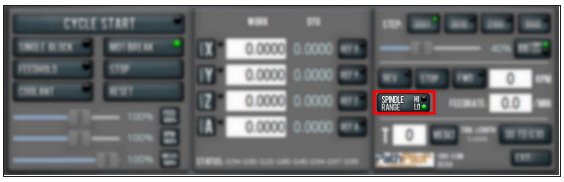


Figure 4-37: Spindle Range button.

   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 4-38: 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 161).

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

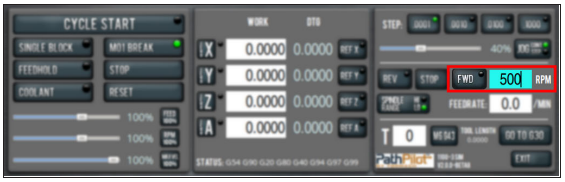


Figure 4-39: Spindle controls.

   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.

4.8 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 107).

4.8.1 Set Up the Automatic Oiler 55
4.8.2 Install the Power Drawbar 56
4.8.3 Install the Flood Coolant Kit 64
4.8.4 Install the Automatic Tool Changer (ATC) 66
4.8.5 Install the 4th Axis 76
4.8.6 Install the Chip Pans 82
4.8.7 Install the Backsplash and Splash Guard 84
4.8.8 Install the Enclosure 84
4.8.9 Set up the Door Lock Switch Kit (Optional) 95
4.8.10 Install the PathPilot Operator Console 99

4.8.1 Set Up the Automatic Oiler

If you installed an automatic oiler, you must now set it up. Complete the following steps in the order listed:

Look for Leaks and Clear the Lines 55
Specify the Interval Time 55
Specify the Actuation Time 55

Look for Leaks and Clear the Lines

1. Power on the oiler.
2. On the oiler's control panel, push and hold the **Feed** button for two seconds.
   The oiler pushes oil through the distribution system.
3. Examine the distribution system to make sure that oil doesn't leak while the system is operating.

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.

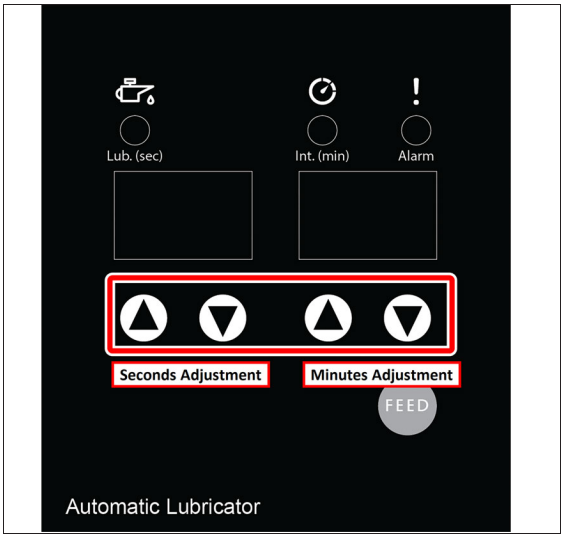


Figure 4-40: Automatic oiler control panel.

The oiler beeps.

2. While looking at the **Minutes** display, do one of the following:
   - To increase the interval time, push the **Up Arrow**. We recommend that you set it to 480 minutes (eight hours).
   - 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**. We recommend that you set it to 12 seconds.
   - 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.

4.8.2 Install the Power Drawbar

Complete the following steps in the order listed:

Required Tools 56
Air Requirements 56
Installation 56
Adjust the Power Drawbar 62

Required Tools

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

- Adjustable wrench (two)
- Clean cloth
- Electric drill
- Hardware to install the FRL Filter-Regulator-Lubricator
- Metric hex wrench set
- Paint pen
- Tooling to drill holes for the FRL Filter-Regulator-Lubricator

Air Requirements

You must verify that the site conforms to the following air supply requirements.
The Power Drawbar uses compressed air to release tools held in the spindle.

- **Air Pressure** Between 90 psi and 120 psi (620 kPa to 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 FRL Filter-Regulator-Lubricator (PN 32457) (included with the power drawbar kit) for this purpose.

Installation

> **Note:** We're continuously improving our products, so your machine may vary from the photos in our documents and videos. For example, on newer machines, the pneumatic lines are mounted on the front of the Power Drawbar to prevent them from getting entangled or pinched in the spindle door. While the images may vary, the concepts still apply.

Complete the following steps in the order listed:

Prepare the Machine 56
Disassemble the Original Drawbar 56
Assemble the Power Drawbar 57
Install the FRL 60
Set Up the FRL 61
Make Air Connections 61

Prepare the Machine

1. If there's already a Tormach Tooling System (TTS) tool holder in the spindle, remove it.
2. Verify that you can access the inside of the spindle cabinet: jog the Z-axis down (-Z) until it is about 6 in. (15 cm) from the machine table.
3. 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.

Disassemble the Original Drawbar

> **CAUTION!** Loose Objects Hazard: The original drawbar contains spring-loaded hardware, which could quickly become loose, causing serious injury.

⚠ Before disassembling the original drawbar, you must put on safety eyewear that meets ANSI Z87+.

1. Put on safety eyewear.
2. Open the spindle door.
3. While using one hand to support the Tormach Tooling System (TTS) collet, use the other to turn and remove the original drawbar.
4. Set the collet and the original drawbar aside.
5. While using one hand to hold the spindle lock arm, use the other to remove the spindle lock arm pivot screw with a 5 mm hex wrench.

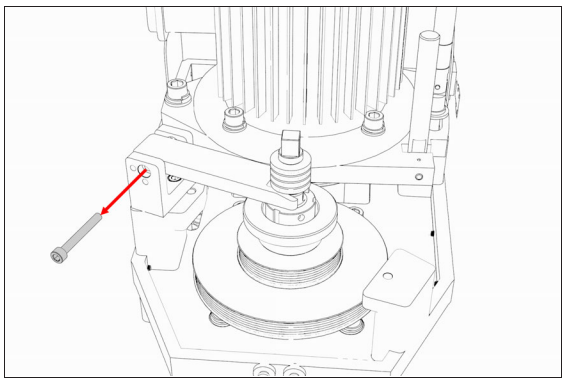


Figure 4-41: Spindle lock arm pivot screw removed from the original drawbar assembly.

Note: The spindle lock arm assembly contains spring-loaded hardware, which could quickly become loose.

6. Carefully remove the spindle lock arm.

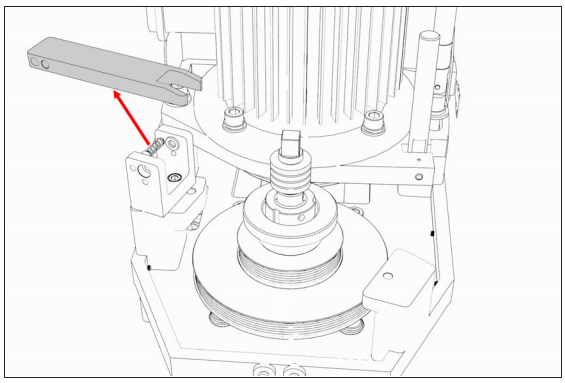


Figure 4-42: Spindle lock arm removed from the original drawbar assembly.

7. Remove the spindle lock base and its components with a 5 mm hex wrench.

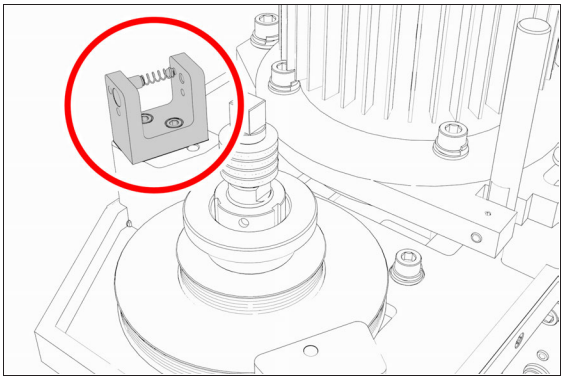


Figure 4-43: Spindle lock base from the original drawbar assembly.

Note: Keep all components for future use. The original drawbar, drawbar bushing, and spindle lock are all required to operate the machine if you later decide to remove the Power Drawbar.

8. Wipe all exposed drawbar mounting surfaces inside the spindle motor cabinet with a clean cloth.
9. Remove the spindle lock arm on the spindle door.

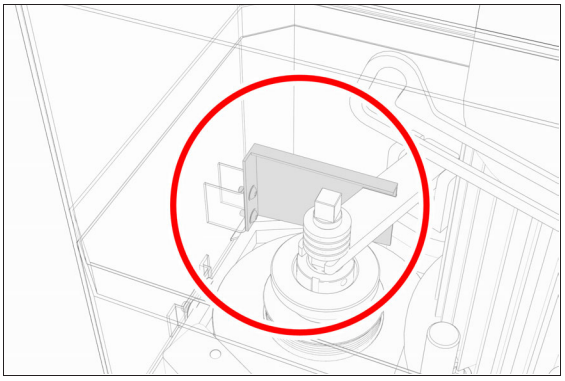


Figure 4-44: Spindle lock arm on the spindle door.

Assemble the Power Drawbar

1. Find the drawbar that you set aside in "Disassemble the Original Drawbar" (on the previous page).
2. Remove the drawbar bushing from the drawbar, and set it aside.
3. Put Anti-Seize (provided) on the bottom of the drawbar head.
4. Find the eight spring washers provided.

5. Move one spring washer on the drawbar, with the convex side of the spring washer toward the drawbar head.

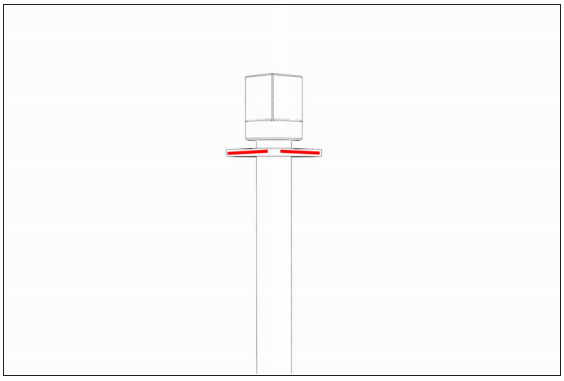


Figure 4-45: Convex side of the spring washer toward the drawbar head.

6. Move another spring washer on the drawbar, with the concave side of the spring washer toward the concave side of the spring washer from Step 5.

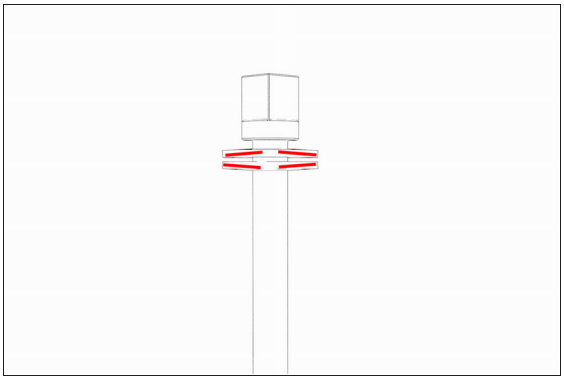


Figure 4-46: Concave sides of two spring washers together.

7. Put Anti-Seize on the edge of the contact surface between the pair of spring washers that you put on the drawbar in Steps 5 and 6.
8. Repeat Steps 5 through 7 for the remaining six spring washers. Make sure that you put Anti-Seize on the spring washers at every contact point.
9. Examine the stack of spring washers. Make sure that all eight spring washers are on the drawbar and arranged in four sets of opposing pairs.

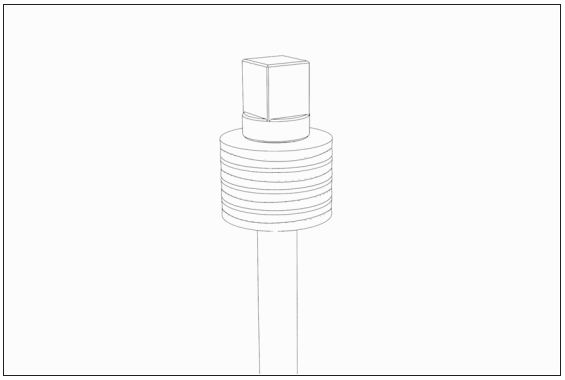


Figure 4-47: All eight spring washers on the drawbar.

10. Find the drawbar bushing that you set aside in Step 2, and put it on the drawbar. Make sure that the smaller diameter of the drawbar bushing is toward the bottom of the drawbar.
11. Put Anti-Seize on the top of the drawbar bushing.
12. Put Anti-Seize on the bottom threads of the drawbar.

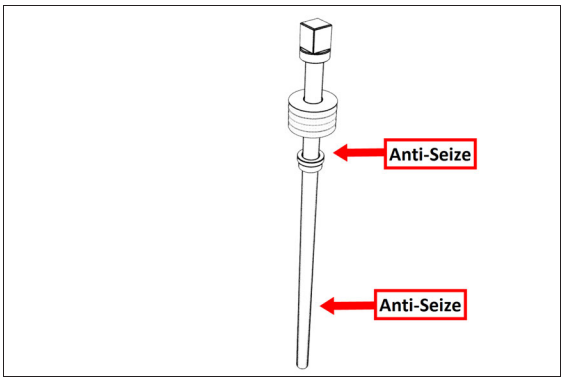


Figure 4-48: Locations to apply Anti-Seize on the drawbar assembly.

13. Put Anti-Seize on the outside taper of the Tormach Tooling System (TTS) collet. Make sure that there is no Anti-Seize on the inside of the collet.
14. Put the drawbar assembly into the spindle.

15. While using one hand to insert the collet into the spindle, use the other to turn the drawbar into the collet.

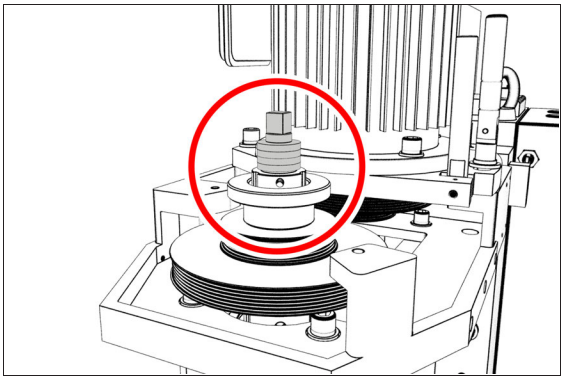


Figure 4-49: Drawbar assembly installed in the spindle motor cabinet.

16. Hand-tighten the drawbar.
17. While using one hand to insert an empty Tormach Tooling System (TTS) tool holder into the collet, use the other to tighten the collet into the drawbar with an adjustable wrench.
18. Use two large, adjustable wrenches to tighten the Power Drawbar until the spring washer stack is compressed to a height of 3/4 in. (20 mm).

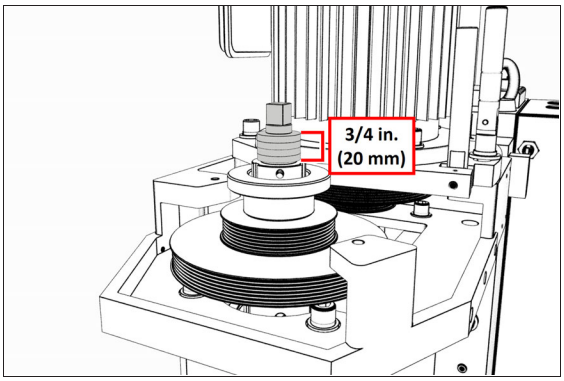


Figure 4-50: Correctly compressed spring washer stack.

> **Note:** Later in this procedure, after you complete the initial installation, you'll do a final drawbar tension adjustment. For more information, see "Adjust the Drawbar Tension" (page 73).

19. Find the Power Drawbar cylinder assembly provided.
20. Identify the Power Drawbar mounting surfaces inside of the spindle motor cabinet, as shown in the following image.

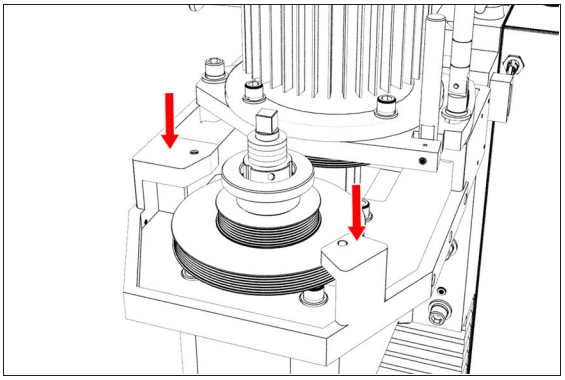


Figure 4-51: Power Drawbar mounting surfaces inside of the spindle motor cabinet.

21. Put the Power Drawbar cylinder assembly on the mounting surface.
22. Find the 10 mm shoulder screw provided, and then put Anti-Seize on its threads.
23. Install the 10 mm shoulder screw on the Power Drawbar cylinder's mount plate with a 5 mm hex wrench.

> **Note:** The head of the shoulder screw will protrude above the mounting plate when the thread of the shoulder screw is fully installed.

The unit, which floats by design, is now securely installed to the spindle head.

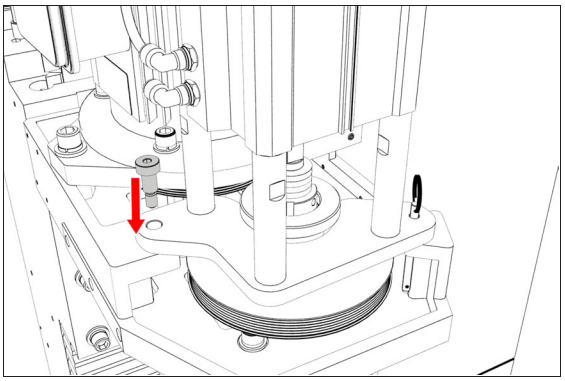


Figure 4-52: 10 mm shoulder screw installed on the Power Drawbar cylinder's mount plate.

24. Find the quick-release pin provided, and then insert it into the Power Drawbar cylinder's mount plate.
    The quick-release pin allows the Power Drawbar cylinder to pivot within the spindle motor cabinet.

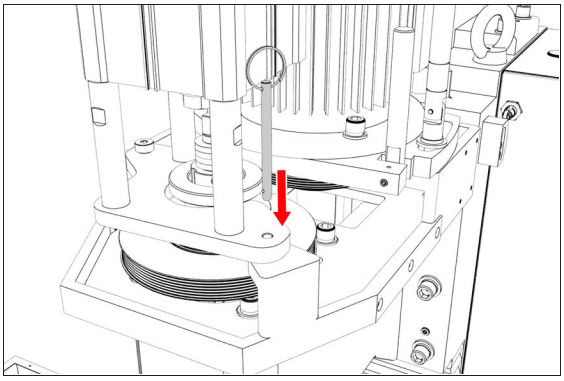


Figure 4-53: Quick-release pin inserted into the Power Drawbar cylinder's mount plate.

Install the FRL

> **Note:** We're continuously improving our products, so your machine may vary from the photos in our documents and videos. While the images may vary, the concepts still apply.

1. Clean the FRL to make sure that it's free of dust.
2. Remove and discard the plastic inserts from the FRL.
3. Identify the dial provided, and then put two layers of thread seal tape on its threads.
4. Attach the dial on the front of the FRL.
5. Identify the two push-to-connect elbows and the two NPT reducers provided. Connect the push-to-connect elbows to the NPT reducers.
6. Put two layers of thread seal tape on the threads of the NPT reducers.
7. Attach the NPT reducers to the valve housings on either side of the FRL.

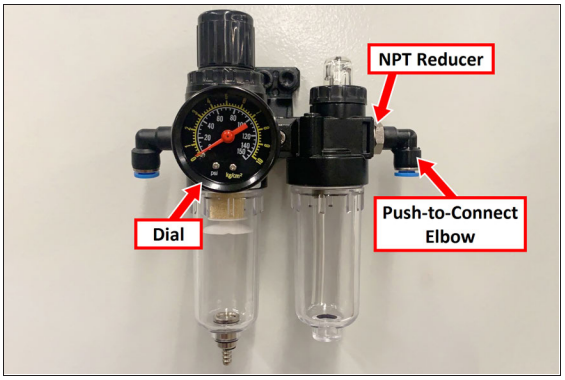


Figure 4-54: FRL assembled.

8. Identify the two holes on the back of the column. This is the mounting location for the FRL.

Figure 4-55: FRL installed on the machine.

9. Install the FRL bracket on the machine with your own hardware.
10. Connect the air lines to the quick-connect bushings.

Set Up the FRL

1. Open the fill port on the FRL with a hex wrench.

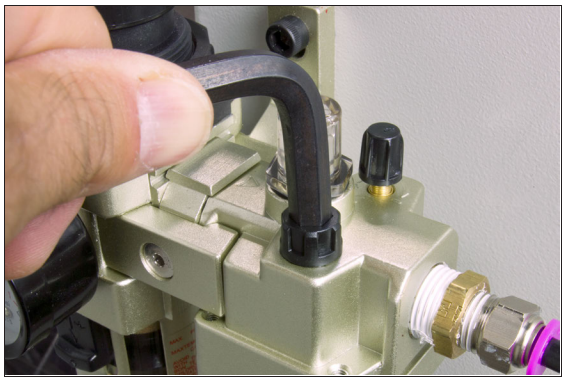


Figure 4-56: Fill port on an FRL.

2. Fill the lubricator bowl with standard air tool oil with a small funnel. You must only use oil specifically designed for air tools.
3. Turn the adjustment knob halfway toward the **+**.
4. Flush all air bubbles from the system.
5. Examine the sight window for air bubbles. When there are no air bubbles in the sight window, and a drop of lubricant is on the bottom of the stem, turn the adjustment knob one-quarter turn back.

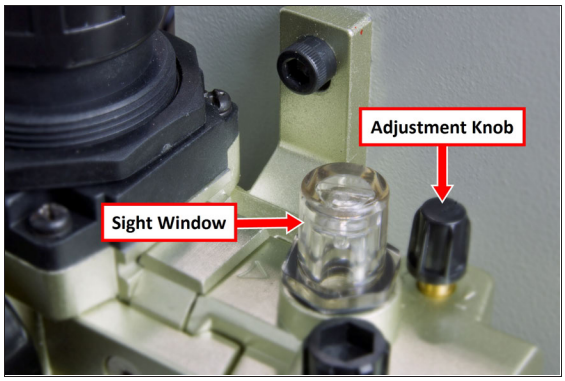


Figure 4-57: Components to flush the air from the FRL.

6. Close the fill port on the FRL with your hand.

> ***NOTICE!*** Don't use a hex wrench to close the fill port. If you do, you could over-tighten it and break the plastic cap.

Make Air Connections

> **Note:** If you have an (optional) Automatic Tool Changer (ATC), install it now.

1. Find the button box assembly provided.
2. Remove four M5 × 0.8 - 10 button head screws securing the cover to the button box with a 3 mm hex wrench. Then, remove the cover.
3. Install the button box base, standoffs, and button assembly on the mill head with two M4 × 0.7 - 50 socket head cap screws.

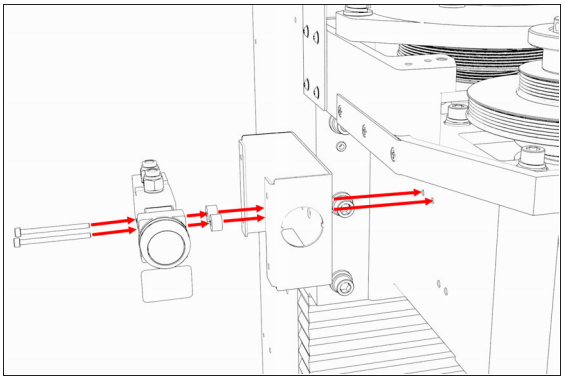


Figure 4-58: Button box base installed on the mill head.

4. Remove and discard the shipping plugs on the Power Drawbar.
5. Find the Retract (white) air line provided. Then, connect one end to the Retract port on the Power Drawbar button.

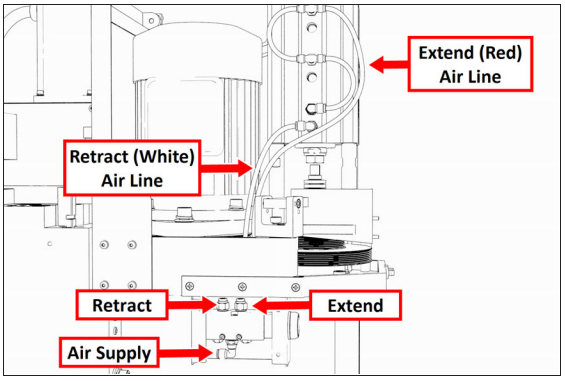


Figure 4-59: Power Drawbar air line routing.

6. Route the loose end of the Retract air line to the Power Drawbar cylinder, and then connect it to the lowest elbow fitting.

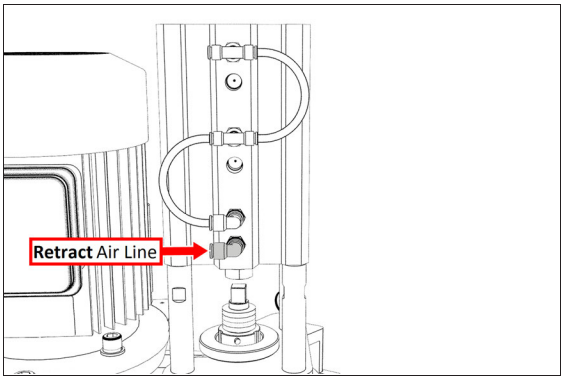


Figure 4-60: Retract fitting on the Power Drawbar cylinder.

7. Find the Extend (red) air line provided. Then, connect one end to the Extend port on the Power Drawbar button.
8. Route the loose end of the Extend air line to the Power Drawbar cylinder, and then connect it to the top tee fitting.

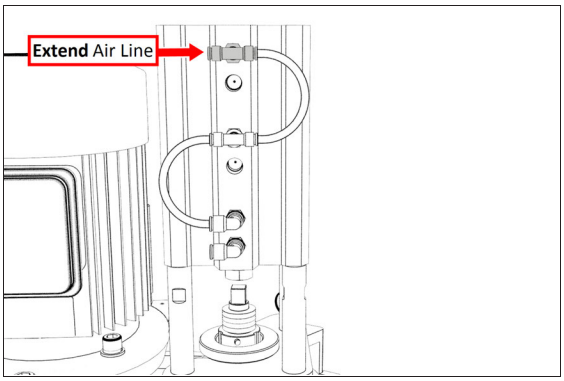


Figure 4-61: Extend fitting on the Power Drawbar cylinder.

9. Use the three cable ties to secure both air lines together.
10. Find the 1/4 in. plastic tube provided. Then, connect one end to the Air Supply push-to-connect elbow on the Power Drawbar button.
11. Route the loose end of the 1/4 in. plastic tube through the energy chain and toward the FRL

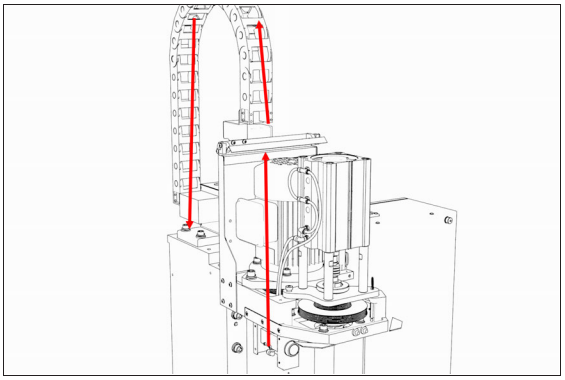


Figure 4-62: Air line routing through the energy chain.

12. Connect the 1/4 in. plastic tube to the Output port on the FRL.
13. Find the 1/4 in. plastic tube provided. Then, connect one end to the Input port on the FRL.
14. Put the 1/4 in. push-connect air fitting adapter on the loose end of the 1/4 in. plastic tube.
15. Route the 1/4 in. plastic tube to your shop's air supply and connect it with the adapter.
16. Replace the button box cover with a 3 mm hex wrench and the screws that you set aside in Step 2.

Adjust the Power Drawbar

After installing the Power Drawbar, you must adjust it.

> ***NOTICE!*** After the initial installation, you must complete a final drawbar tension adjustment. For more information, see "Adjust the Drawbar Tension" (page 73). If you don't complete a drawbar tension adjustment, there's a risk of tool pull-out.

Complete the following steps in the order listed:

Adjust the Drawbar Tension **62**
About Drawbar Tension **63**
Adjust the Initial Setup **63**

Adjust the Drawbar Tension

This adjustment sets the highest possible drawbar tension while still allowing the Power Drawbar cylinder to release the tool. For information, see"About Drawbar Tension" (page 73).

> ***NOTICE!*** After the initial installation, you must examine the drawbar tension weekly. During periods of heavy use,

xamine the drawbar tension more frequently. If you
on't, there's a risk of tool pull-out.

To adjust the drawbar tension:

1. Put an empty Tormach Tooling System (TTS) tool holder into the collet.
2. While using one hand to support the tool holder, use the other to push the Release Tool button.
3. Depending on whether the tool holder releases or not, do one of the following:
   - **If the Tool Holder Releases** Tighten the Power Drawbar in quarter-turn increments with two adjustable wrenches. After each turn, push the Release Tool button. Stop when the tool holder does not release. Then, loosen the Power Drawbar one quarter-turn with two adjustable wrenches.
   - **If the Tool Holder Doesn't Release** Loosen the Power Drawbar in quarter-turn increments with two adjustable wrenches while pushing the Release Tool button. Stop when the tool holder releases.
4. Make a visual reference to help you set or adjust the drawbar tension in the future: use a paint pen to make a witness mark on both the head of the drawbar and the end of the spindle.

About Drawbar Tension

While machining, the Tormach Tooling System (TTS) collet holds a Tormach Tooling System (TTS) tool holder in the spindle by applying a clamping force to both the shank and the shoulder of the tool. The tension force that is applied to the drawbar pulls the Tormach Tooling System (TTS) collet into the spindle taper, which then applies the clamping force to the Tormach Tooling System (TTS) tool.
The force on the drawbar — known as drawbar tension — is applied differently depending on the tool changing method:

- **Automatic (using the Power Drawbar)** Tension is applied by the compressed spring washers.
- **Manual** Tension is applied when you tighten the drawbar into the collet using a wrench.

Adjust the Initial Setup

In this adjustment, you'll verify that there's enough clearance between the end of the drawbar and the Power Drawbar cylinder.

NOTICE! If you don't do this adjustment, there's a risk that the drawbar can loosen, or that operations can be louder than normal.

1. Examine the space between the hex head screw on the Power Drawbar cylinder's rod and the top of the drawbar.

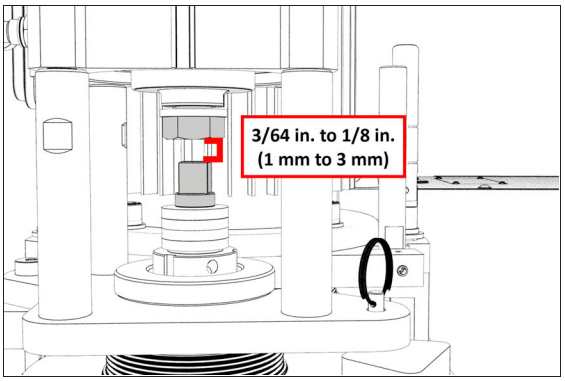


Figure 4-63: Correctly spaced drawbar and Power Drawbar cylinder.

2. Verify that the gap is between 3/64 in. and 1/8 in. (1 mm and 3 mm). Depending on the size of the gap, do one of the following:
   - **Between 3/64 in. and 1/8 in. (1 mm and 3 mm)** You have completed adjusting the initial setup. Go to Operation.
   - **Less Than 3/64 in. (1 mm)** Go to Step 3.
3. Disconnect the shop's air supply from the Power Drawbar button.
4. Pull out the quick-release pin.
5. Pivot the Power Drawbar cylinder assembly to the left so that you can access the Power Drawbar cylinder's rod.

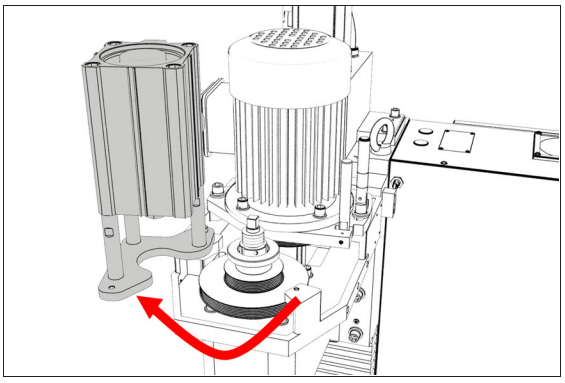


Figure 4-64: Power Drawbar cylinder pivoted to the left.

6. Remove the hex head screw on the Power Drawbar cylinder's rod with an adjustable wrench, and set it aside.

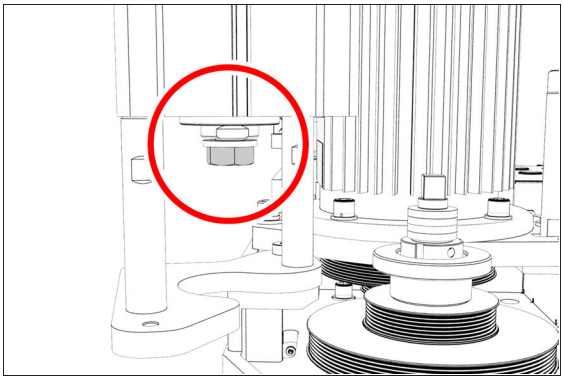


Figure 4-65: Hex head screw on the Power Drawbar cylinder's rod.

7. Remove the M16 washer from the Power Drawbar cylinder's rod, and set it aside.

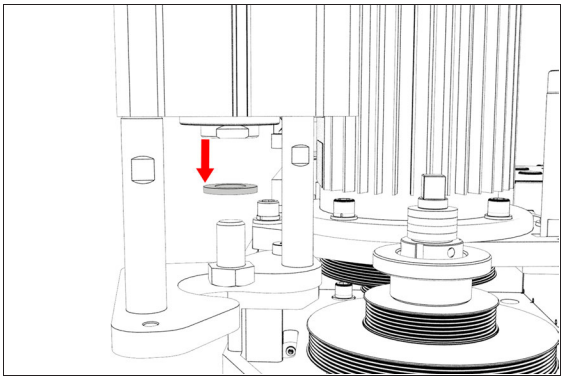


Figure 4-66: M16 washer removed from the Power Drawbar cylinder's rod.

8. Put the hex head screw back in, and then tighten it completely with an adjustable wrench.
9. Pivot the Power Drawbar cylinder to the original location.
10. Push in the quick-release pin.
11. Reconnect the shop's air supply to the Power Drawbar button.
12. Examine the space between the hex head screw on the Power Drawbar cylinder's rod and the top of the drawbar.
13. Verify that the gap is between 3/64 in. and 1/8 in. (1 mm and 3 mm). Depending on the size of the gap, do one of the following:
    - **Between 3/64 in. and 1/8 in. (1 mm and 3 mm)** You have completed adjusting the initial setup.
    - **Less Than 1/8 in. (1 mm)** Go to Step 14.
14. Find the three provided M14 flat washers.
15. Put one M14 flat washer under each mounting post on the Power Drawbar cylinder.

4.8.3 Install the Flood Coolant Kit

Complete the following steps in the order listed:

Adjust the Coolant Pump Motor Strapping **64**
Set Up the Flood Coolant Kit **65**

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:
    - **1100 (All Models)** 220 Vac (high volt)
    - **770 (All Models)** 120 Vac (low volt)

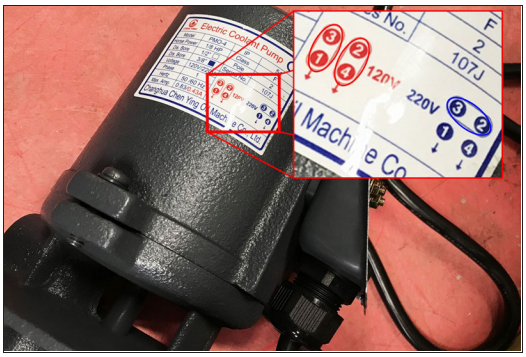


Figure 4-67: Coolant pump motor jumper configuration diagram.

2. Remove the access cover on the coolant pump.
3. Reference the configuration diagram and move the jumper to the 120 Vac (low volt) position. Don't change the position of any wires – just the jumper that connects the terminals.

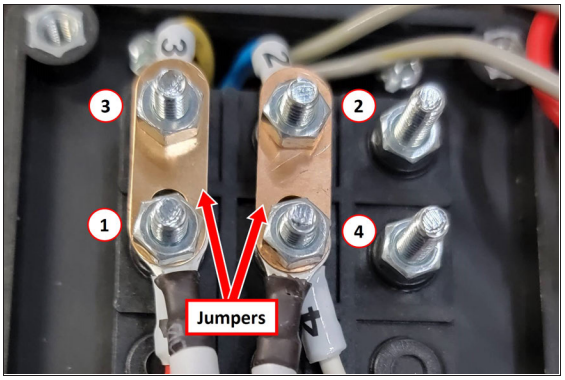


Figure 4-68: Coolant pump motor strapping adjusted

for 120 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.

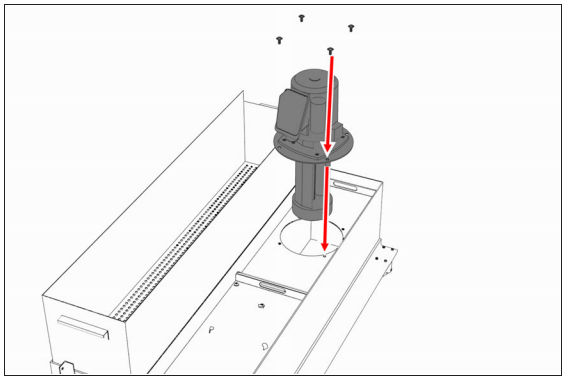


Figure 4-69: Coolant pump and its hardware moving into the coolant tank.

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

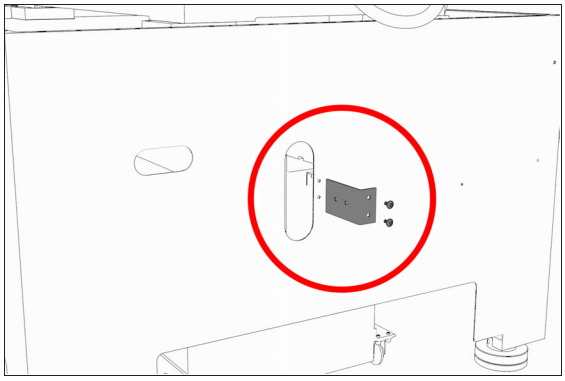


Figure 4-70: Coolant hose bracket and its hardware removed from the Machine Stand.

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.

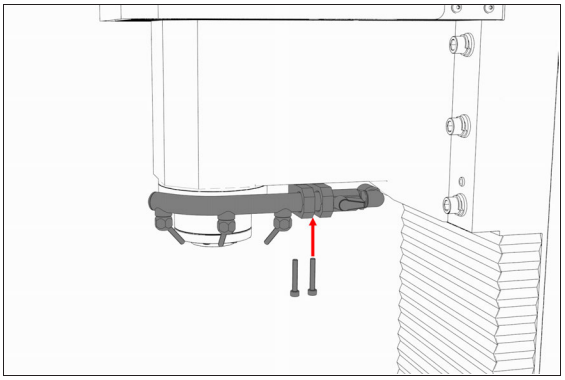


Figure 4-71: Attaching the coolant manifold to the spindle nose.

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.

4.8.4 Install the Automatic Tool Changer (ATC)

Complete the following steps in the order listed:

Required Tools 66
Air Requirements 66
Before You Begin 66
Disassemble the Power Drawbar Button 67
Install the Air Cylinder 67
Mount the Automatic Tool Changer (ATC) Bracket 67
Install the Main Assembly 68
Level the Automatic Tool Changer (ATC) 68
Make Air Connections 71
Make Electrical Connections 71
Verify the Installation 72
Adjust the Power Drawbar 73
Adjust the Tool Tray Load Position 75
Verify the Alignment 75
Set the Tool Change Height 76
Adjust for Rotational Play 76

Required Tools

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

Required Tools for Installation

- 1-1/2 in. adjustable wrench
- Marker
- Metric hex wrench set
- Phillips screwdriver
- Small, flat-head screwdriver
- Snips
- Socket wrench and a 13 mm socket

Required Tools for Verification

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

Air Requirements

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

- **Air Pressure** Between 90 psi and 120 psi (620 kPa to 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 FRL Filter-Regulator-Lubricator (PN 32457) (included with the power drawbar kit) for this purpose.

Before You Begin

1. If there's a tool holder in the spindle, remove it.
2. Remove any accessories or fixtures from the machine table.
3. 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.

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

4. Update your controller: From the **Status** tab, select **Update**. Then, follow the on-screen instructions. Once the controller is updated to the latest version of PathPilot, go to Step 5.

> **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.

5. 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.

Disassemble the Power Drawbar Button

1. Depending on your machine's setup, do one of the following:
   - If you're installing an Automatic Tool Changer (ATC) on a new machine, skip this procedure and go to "Install the Air Cylinder" (below).
   - If you previously installed the Power Drawbar button assembly, you must first disassemble it. Go to Step 2.
2. Disconnect the shop air supply from the machine.
3. Disconnect all air lines from the Power Drawbar button.
4. Remove four M5 × 0.8 - 10 mm button head cap screws that secure the Power Drawbar button cover.
5. Remove two M4 × 0.7 - 50 mm socket head cap screws that secure the Power Drawbar button to the spindle head.
6. Remove the Power Drawbar button from the spindle head.

Install the Air Cylinder

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

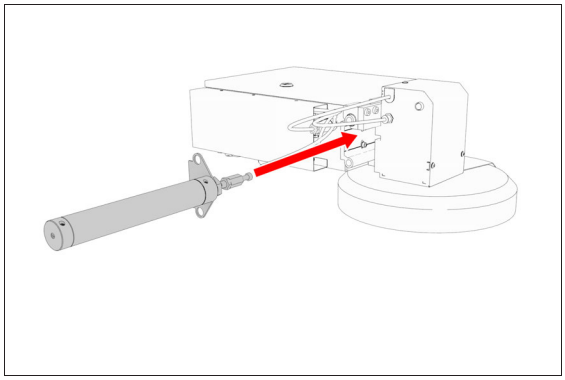


Figure 4-72: Putting the air cylinder into the ATC main assembly.

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.

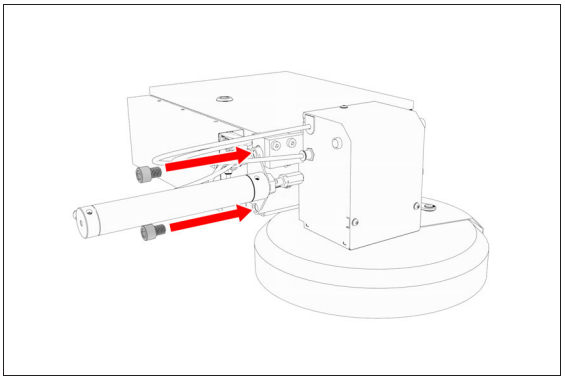


Figure 4-73: Putting the air cylinder hardware into the air cylinder.

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.

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.

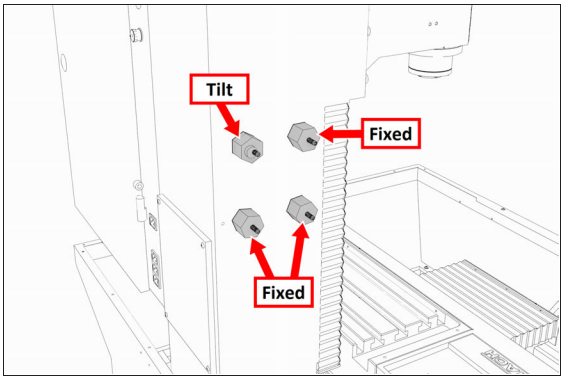


Figure 4-74: Four standoffs installed on the Z-column.

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

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

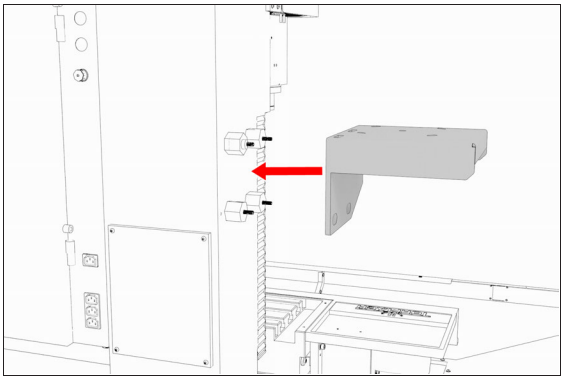


Figure 4-75: ATC mounting bracket moving on to the four standoffs.

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

7. Secure the bracket by reinstalling the washers and flange nuts that you removed in Step 2 with a 13 mm socket.
8. 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

1. 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.

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

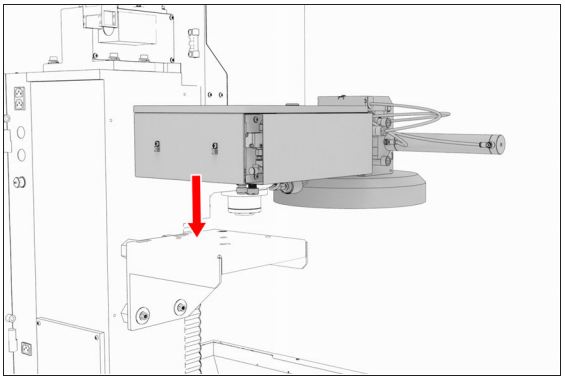


Figure 4-76: ATC main assembly positioned above the mounting bracket.

3. Align the locating pin on the ATC main assembly with the matching hole in the mounting bracket.
4. 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.

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 **68**
Examine Perpendicularity in the Y Direction **69**
Examine Perpendicularity in the X Direction **69**
Examine the Alignment of the Carousel Door Opening **70**

Prepare the Machine

1. Push the tool tray toward the spindle.

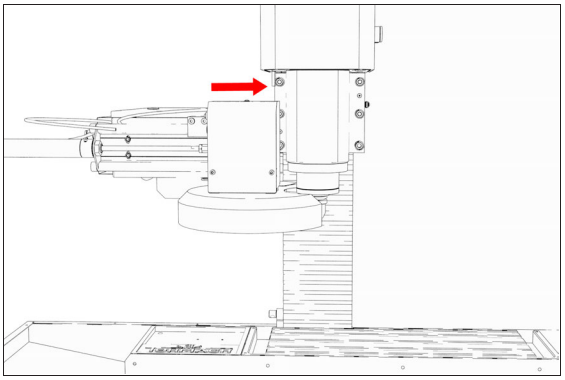


Figure 4-77: Tool tray moved in toward the spindle.

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

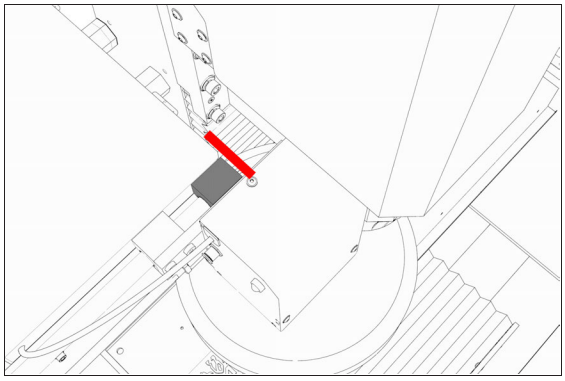


Figure 4-78: Linear bearing flush with the ATC main assembly.

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. Don't rest the tool holder on top of the fork.

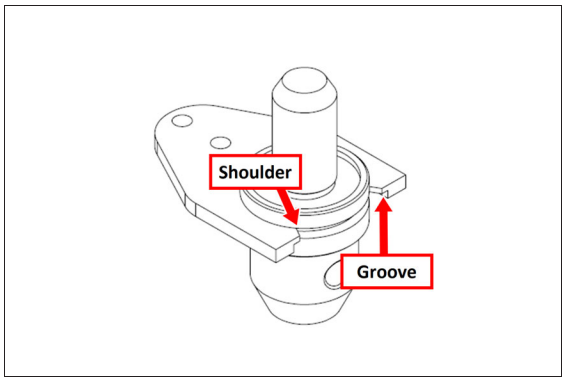


Figure 4-79: Groove on a Tormach Tooling System (TTS) aligned with the shoulder of an ATC fork.

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.

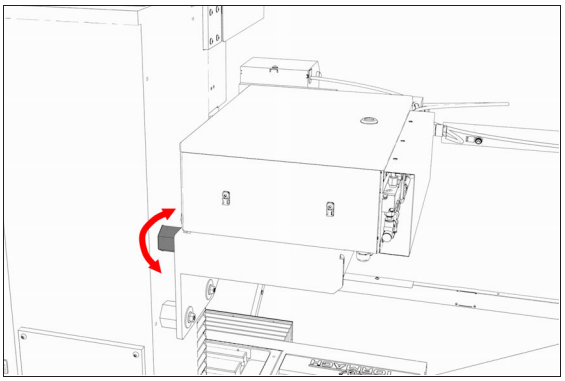


Figure 4-80: Tilt standoff.

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.

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

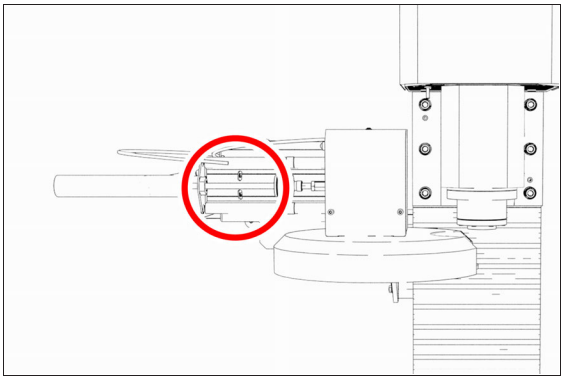


Figure 4-81: Socket head cap screws on the linear rails.

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 Reset 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.

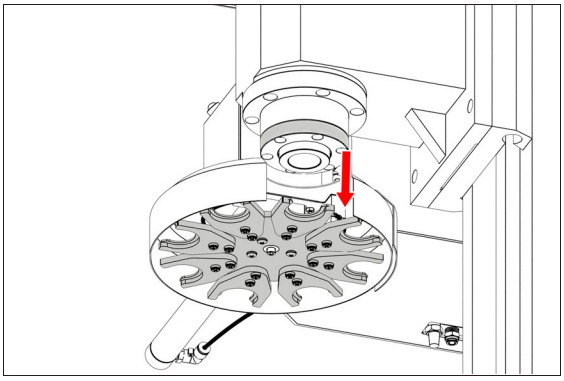


Figure 4-82: Distance between the carousel door opening and the spindle mounting flange.

- 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.

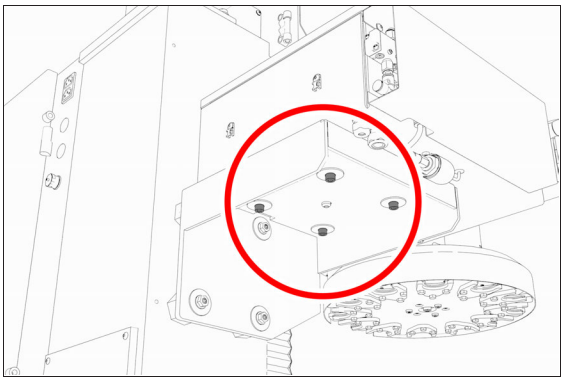


Figure 4-83: Socket head cap screws securing the ATC main assembly to the mounting bracket.

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 69).

   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.

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.

> **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. 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.

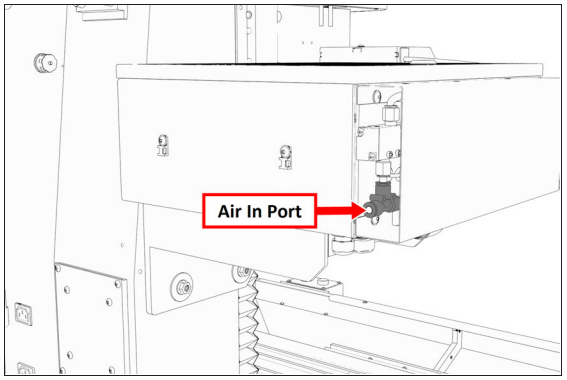


Figure 4-84: Air in port in the ATC main assembly.

   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 Reset button.
   d. Bring the machine out of reset and reference it.

> **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.

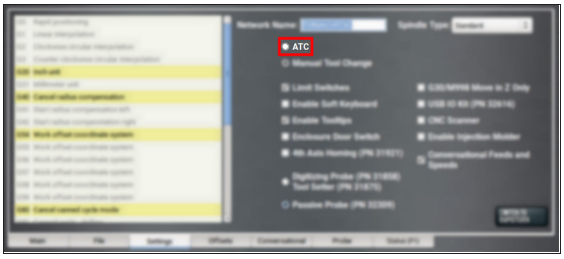


Figure 4-85: ATC radio button on the Settings tab.

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 collet open button on the side of the ATC.

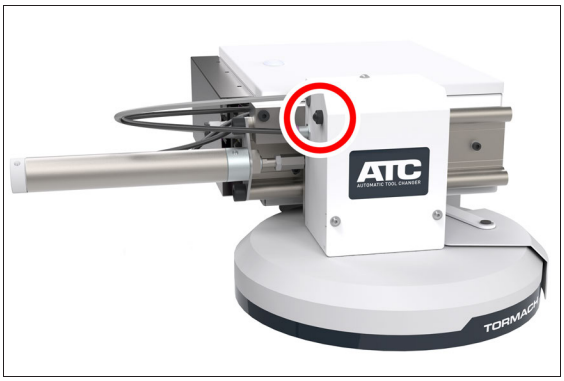


Figure 4-86: Collet open button on the side of the ATC.

   The collet opens.
   b. Load a tool into the spindle.
   c. Release the button.
   The collet 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 4-87: 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.

Adjust the Power Drawbar

If you have not yet done so, you must adjust the Power Drawbar. Complete the following steps in the order listed:

Adjust the Drawbar Tension **73**
About Drawbar Tension **73**
Adjust the Initial Setup **73**

Adjust the Drawbar Tension

This adjustment sets the highest possible drawbar tension while still allowing the Power Drawbar cylinder to release the tool. For information, see"About Drawbar Tension" (below).

> ***NOTICE!*** After the initial installation, you must examine the drawbar tension weekly. During periods of heavy use, examine the drawbar tension more frequently. If you don't, there's a risk of tool pull-out.

To adjust the drawbar tension:

1. Put an empty Tormach Tooling System (TTS) tool holder into the collet.
2. While using one hand to support the tool holder, use the other to push the Release Tool button.
3. Depending on whether the tool holder releases or not, do one of the following:
   - **If the Tool Holder Releases** Tighten the Power Drawbar in quarter-turn increments with two adjustable wrenches. After each turn, push the Release Tool button. Stop when the tool holder does not release. Then, loosen the Power Drawbar one quarter-turn with two adjustable wrenches.
   - **If the Tool Holder Doesn't Release** Loosen the Power Drawbar in quarter-turn increments with two adjustable wrenches while pushing the Release Tool button. Stop when the tool holder releases.
4. Make a visual reference to help you set or adjust the drawbar tension in the future: use a paint pen to make a witness mark on both the head of the drawbar and the end of the spindle.

About Drawbar Tension

While machining, the Tormach Tooling System (TTS) collet holds a Tormach Tooling System (TTS) tool holder in the spindle by applying a clamping force to both the shank and the shoulder of the tool. The tension force that is applied to the drawbar pulls the Tormach Tooling System (TTS) collet into the spindle taper, which then applies the clamping force to the Tormach Tooling System (TTS) tool.
The force on the drawbar — known as drawbar tension — is applied differently depending on the tool changing method:

- **Automatic (using the Power Drawbar)** Tension is applied by the compressed spring washers.
- **Manual** Tension is applied when you tighten the drawbar into the collet using a wrench.

Adjust the Initial Setup

In this adjustment, you'll verify that there's enough clearance between the end of the drawbar and the Power Drawbar cylinder.

> ***NOTICE!*** If you don't do this adjustment, there's a risk that the drawbar can loosen, or that operations can be louder than normal.

1. Examine the space between the hex head screw on the Power Drawbar cylinder's rod and the top of the drawbar.

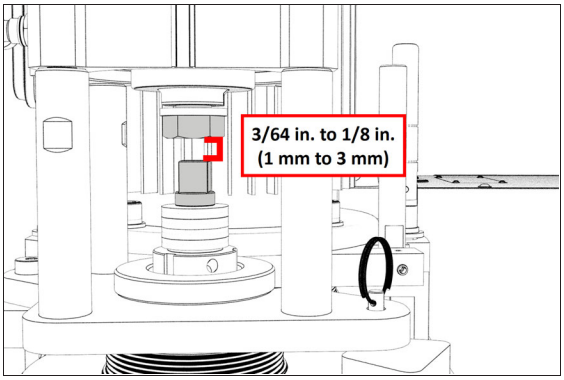


Figure 4-88: Correctly spaced drawbar and Power Drawbar cylinder.

2. Verify that the gap is between 3/64 in. and 1/8 in. (1 mm and 3 mm). Depending on the size of the gap, do one of the following:
   - **Between 3/64 in. and 1/8 in. (1 mm and 3 mm)** You have completed adjusting the initial setup. Go to Operation.
   - **Less Than 3/64 in. (1 mm)** Go to Step 3.
3. Disconnect the shop's air supply from the Power Drawbar button.
4. Pull out the quick-release pin.
5. Pivot the Power Drawbar cylinder assembly to the left so that you can access the Power Drawbar cylinder's rod.

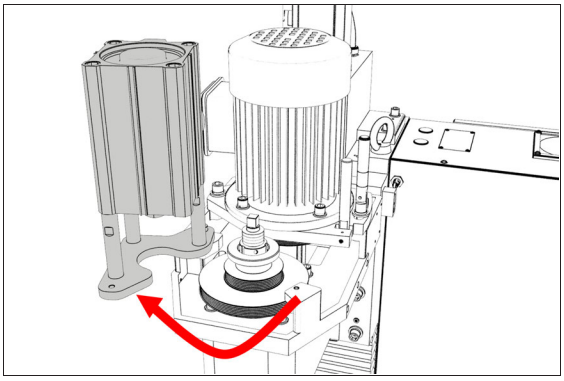


Figure 4-89: Power Drawbar cylinder pivoted to the left.

6. Remove the hex head screw on the Power Drawbar cylinder’s rod with an adjustable wrench, and set it aside.

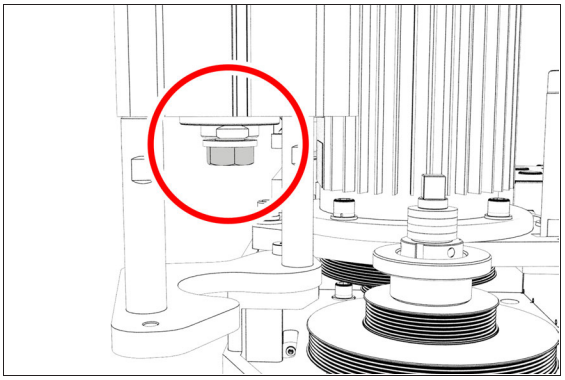


Figure 4-90: Hex head screw on the Power Drawbar cylinder's rod.

7. Remove the M16 washer from the Power Drawbar cylinder’s rod, and set it aside.

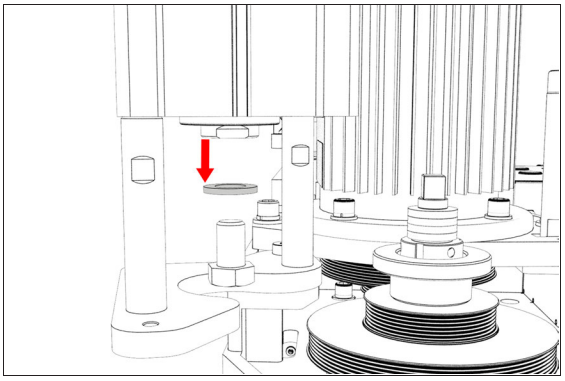


Figure 4-91: M16 washer removed from the Power Drawbar cylinder's rod.

8. Put the hex head screw back in, and then tighten it completely with an adjustable wrench.
9. Pivot the Power Drawbar cylinder to the original location.
10. Push in the quick-release pin.
11. Reconnect the shop's air supply to the Power Drawbar button.
12. Examine the space between the hex head screw on the Power Drawbar cylinder’s rod and the top of the drawbar.
13. Verify that the gap is between 3/64 in. and 1/8 in. (1 mm and 3 mm). Depending on the size of the gap, do one of the following:
    - **Between 3/64 in. and 1/8 in. (1 mm and 3 mm)** You have completed adjusting the initial setup.
    - **Less Than 1/8 in. (1 mm)** Go to Step 14.
14. Find the three provided M14 flat washers.

15. Put one M14 flat washer under each mounting post on the Power Drawbar cylinder.

Adjust the Tool Tray Load Position

1. Verify that there's no tool in the spindle.
2. From the PathPilot interface, on the **ATC** tab, select **Ref Tool Tray**.

Figure 4-92: 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.

3. Select **Go to Tray Load Position**.

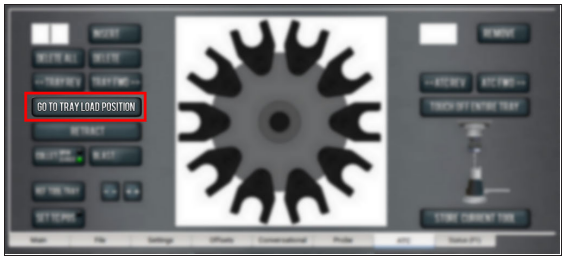


Figure 4-93: Go to Tray Load Position button on the ATC tab.

4. When prompted, select **OK**.
   The tool tray moves forward.
5. Put the tool holder with the rod into the fork.
6. From the PathPilot interface, slowly jog the Z-axis down (-Z) to bring the spindle nose toward the tool in the tool tray.
7. Make sure that the tool's shank is aligned concentrically with the collet in the spindle.
8. If the tool's shank isn't aligned, do the following:
   - **Adjust the Alignment of the Tool in the Y Direction (toward or away from the Z column)** Determine if the tray must move clockwise or counterclockwise. From the PathPilot interface, in the **ATC** tab, either select **--** to step the tool tray counterclockwise or **++** to step the tool tray clockwise.

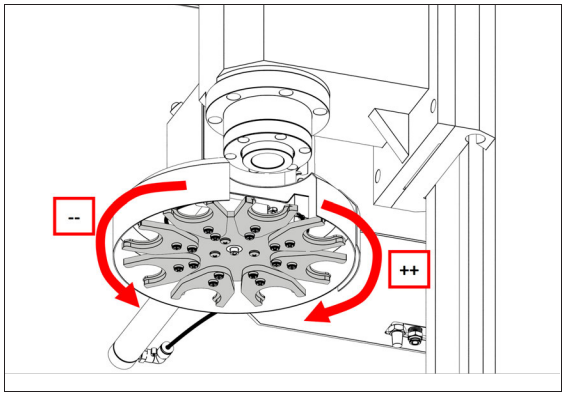


Figure 4-94: Moving the tool tray clockwise or counterclockwise.

   - **Adjust the Alignment of the Tool in the X Direction (left or right)** 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.

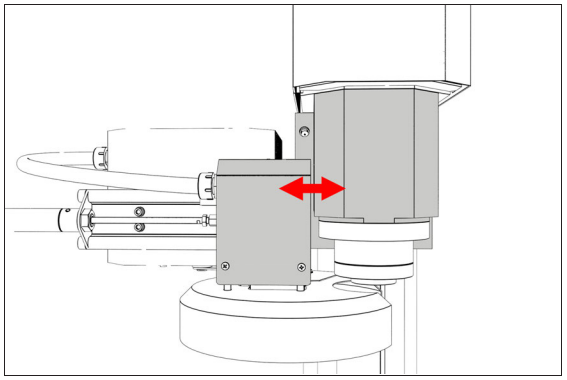


Figure 4-95: Moving the tool tray left or right.

   Repeat adjustments until the tool's shank is concentric with the collet in the spindle.
9. From the PathPilot interface, on the **ATC** tab, select **Retract**.

Verify the Alignment

1. From the PathPilot interface, select **Go to Tray Load Position**.
2. Slowly jog the Z-axis down (-Z) over the tool's shank.
3. Verify that the tool's shank moves freely into the collet.

4. Depending on the tool's shank movement, do one of the following:
   - **Moves Freely** Go to "Set the Tool Change Height" (below).
   - **Doesn't Move Freely** This indicates that the ATC is misaligned and you must realign it. Go to "Adjust the Tool Tray Load Position" (on the previous page).

Set the Tool Change Height

1. From the PathPilot interface, slowly jog the Z-axis down (-Z) over the tool. Stop jogging when the spindle nose just makes contact with the shoulder of the tool holder.
2. On the **ATC** tab, select **Set TC POS**.

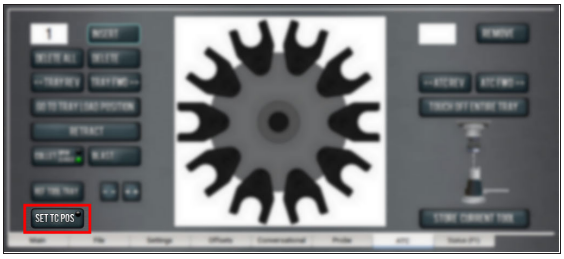


Figure 4-96: Set TC POS button on the ATC tab.

The tool change position is set.

Adjust for Rotational Play

There's a small amount of rotational play built into the Automatic Tool Changer (ATC) carousel. This play allows for some misalignment during tool changes, and you must adjust for it in both directions. The taper on the tool shank also helps align the tool during a tool change.

To adjust for rotational play:

1. From the PathPilot interface, on the **ATC** tab, select **Tray Fwd** to rotate the tray clockwise (forward) one full tool slot.

Figure 4-97: Tray FWD and Tray REV buttons on the ATC tab.

2. Select **Tray Rev** to rotate the tray counterclockwise (backward) one full tool slot.
3. Verify that the tool's shank is aligned with the collet in the spindle.
4. Depending on the alignment, do one of the following:
   - **Aligned** You have completed aligning the ATC. Remove the tool from the fork. Go to Step 5.
   - **Not Aligned** You must readjust the tool tray rotation. Go to "Adjust the Tool Tray Load Position" (on the previous page).
5. From the PathPilot interface, on the **Main** tab, drag the **Maxvel Override** slider to the left. This reduces the maximum velocity by the percentage shown.

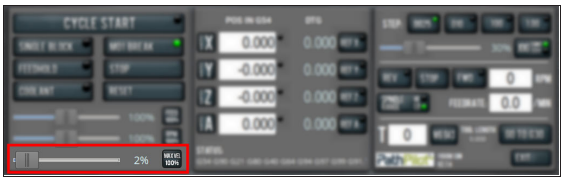


Figure 4-98: Maxvel Override slider on the Main tab.

6. Do a test tool change. Because the maximum velocity is reduced, it's easier to verify the alignment of the ATC and stop the machine if further adjustment is required.

> **Tip!** Use the **Spacebar** key to pause the tool change, if needed.

4.8.5 Install the 4th Axis

Complete the following steps in the order listed:

Install the M/MX A-Axis Driver (PN 38954) **76**
Set Up the 6 in. or 8 in. Rotary Table **78**
Set Up the microARC 4 ..... **80**
Verify the Installation **82**

Install the M/MX A-Axis Driver (PN 38954)

Complete the following steps in the order listed:

Set the Driver DIP Switches **76**
Install the A-Axis Motor Driver **77**

Set the Driver DIP Switches

- Depending on which rotary table you're using, set the DIP switches on the motor driver as detailed in the following tables.

6 in. Standard or Tilting	
Dip Switch	**Position**

1	On
2	On
3	Off
4	Off
5	Off
6	On
7	On
8	Off

6 in. Super Spacer, or 8 in. Standard, Tilting, or Super Spacer

Dip Switch	Position
1	On
2	Off
3	Off
4	Off
5	Off
6	On
7	On
8	Off

M/MX - microARC 4

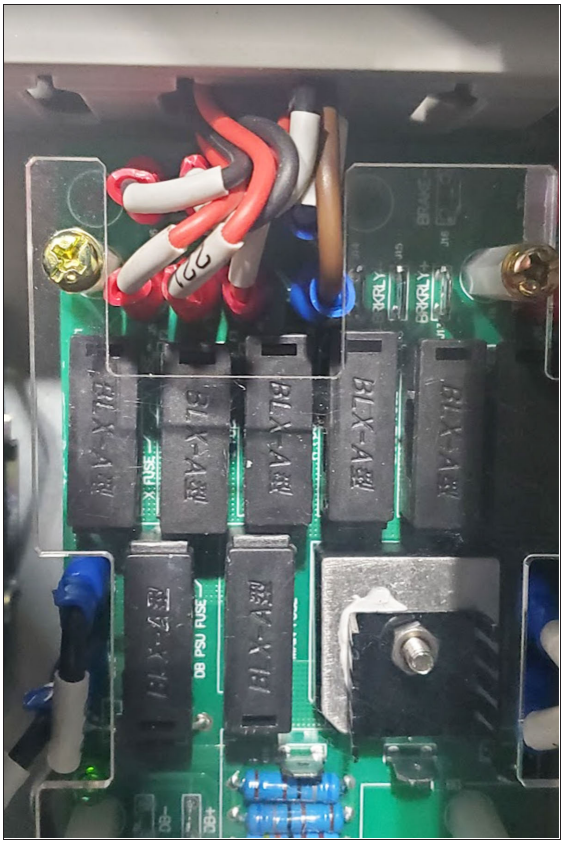
Dip Switch	Position
1	On
2	On
3	Off
4	On
5	On
6	On
7	On
8	Off

Install the A-Axis Motor Driver

> **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.

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. Verify that you've correctly set the DIP switches on your stepper driver.
3. Remove the top, right, and middle (above the DC-BUS board) wire trough covers in the electrical cabinet.
4. Find the ribbon cable (labeled **423.4**) in the top wire trough.
5. Find the green connector and wires in the right wire trough.
6. Install the motor driver in the electrical cabinet with a #2 Phillips screwdriver.
7. Connect the ribbon cable to the motor driver.
8. Apply dielectric grease to the power connector, and then connect it to the motor driver.
9. From the green connector, follow wire 240 (blue) and wire 241 (brown) to where they end in the wire trough and pull them out.

10. Connect the loose end of wire 241 (brown) to the A+ terminal on the DC bus board and connect wire 240 (blue) to the A- terminal of the DC bus board.



11. Put back the wire trough covers.

Set Up the 6 in. or 8 in. Rotary Table

Complete the following steps in the order listed:

Required Tools **78**
Unpack the 4th Axis **78**
Lubricate the Rotary Table **78**
Adjust the Backlash **79**
To Set the Backlash by Positioning the Backlash Adjustment Screw 79
To Set the Backlash by the Numbers 80
Mount the Rotary Table **80**

Required Tools

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

- #2 Phillips screwdriver
- Dead-blow hammer (or similar)
- Magnetic dial indicator
- Newspaper (or similar)

Unpack the 4th Axis

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.
   - 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. Make sure that all loose parts are removed from the package before discarding any shipping materials.

Lubricate the Rotary Table

> ***NOTICE!*** Never operate the 4th Axis without lubrication. Operating the 4th Axis without lubrication may void your warranty.

The rotary table is shipped without oil. Before operating, you must fill the rotary table with oil. Only use AGMA 2 gear oil or SAE 30 weight motor oil. Do not use way oil.

> **Note:** After the rotary table is filled with oil, you must allow it to drain the excess oil, which may take up to two days. You may use the 4th Axis while it drains.

1. Identify the oil fittings on the rotary table.

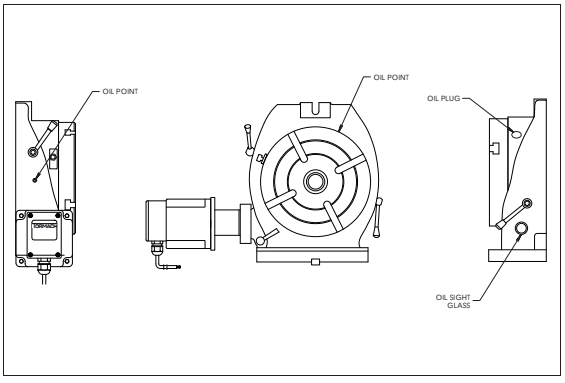


Figure 4-99: Oil fittings on a standard rotary table.

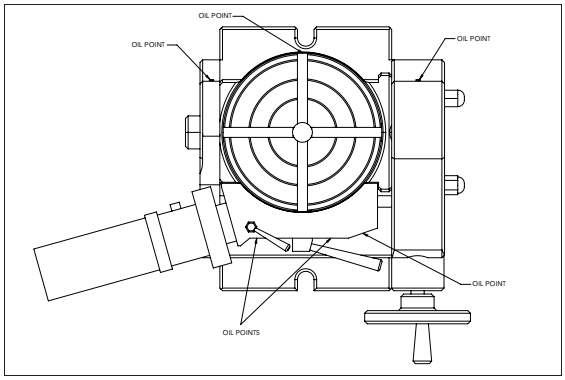


Figure 4-100: Oil fittings on a tilting rotary table.

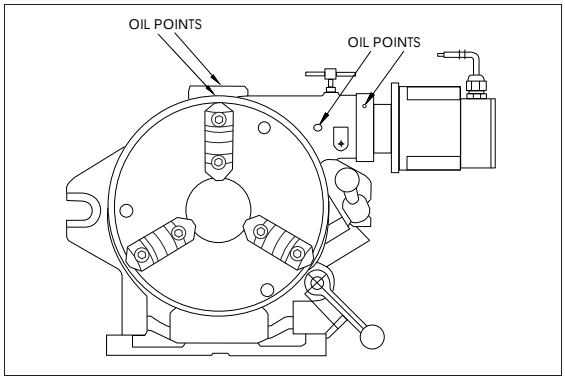


Figure 4-101: Oil fittings on a super spacer rotary table.

2. On the standard rotary tables (6 in. Rotary Table or 8 in. Rotary Table), identify the oil reservoir.
3. Use a trigger-style oil can to fill the oil fittings: Insert the tip of the oil can into each fitting, and pump in oil until you can feel back pressure.
4. On the standard rotary tables (6 in. Rotary Table or 8 in. Rotary Table), fill the oil reservoir until the oil begins to leak out at the bottom of the table. If the If the oil reservoir is over-filled, it slowly leaks out until it reaches the correct level.
5. Put the rotary table on a stack of newspaper (or similar) to allow it to drain the excess oil.

Adjust the Backlash

> ***NOTICE!*** You must complete the steps in this procedure to adjust the backlash. If you do not adjust the backlash, it could result in premature wear on the rotary table.

To Set the Backlash by Positioning the Backlash Adjustment Screw

1. Identify the backlash adjustment screw: Remove the protective cover screw on top of it, or loosen a jam nut.

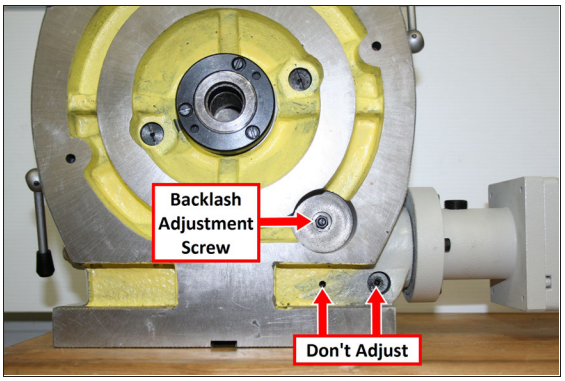


Figure 4-102: Backlash adjustment screw on a standard rotary table.

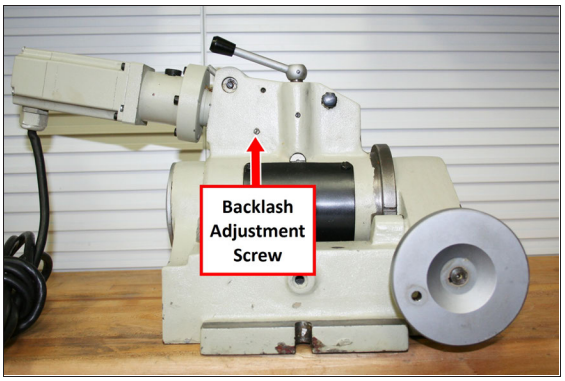


Figure 4-103: Backlash adjustment screw on a tilting rotary table.

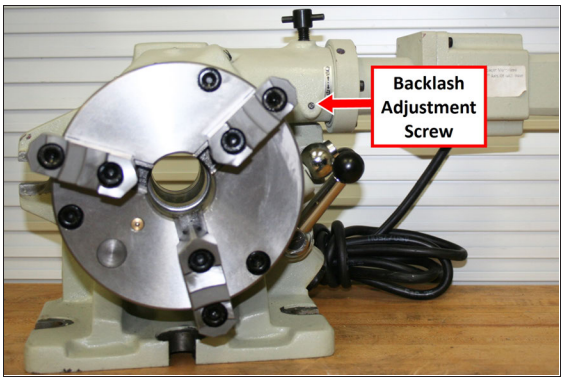


Figure 4-104: Backlash adjustment screw on a super spacer rotary table.

2. Loosen the backlash adjustment screw six turns counterclockwise.
3. Disengage the eccentric lock and clamp handles.

4. Engage the worm gear: Rotate it completely (counterclockwise on standard and tilting rotary tables; clockwise on super spacer rotary tables).
5. Verify that the rotary table does not turn. It doesn't turn when the motor is engaged.
6. Use one hand to put counterclockwise pressure on the motor (clockwise on super spacer rotary tables), and slowly tighten the set screw until you feel resistance to the pressure you're applying.

> **Tip!** Move slowly — the resistance could be subtle.

   The set screw is just against the worm drive.
7. Tighten the set screw a quarter-turn. The motor rotates slightly, and creates a gap (for an oil film) between table and worm gear.
8. Replace the protective cover screw.

To Set the Backlash by the Numbers

- Adjust for a minimum backlash of 30 arc-seconds. Measured at the outer circumference of an 8-in. diameter circle with a dial indicator, 30 arc-seconds will be 0.0006 in. of lost motion.

Setting the backlash to 60 arc-seconds will sustain a thicker oil film, yielding lower friction and longer life. Measured at the outer circumference of an 8-in. diameter circle with a dial indicator, 60 arc-seconds is 0.0012 in. of lost motion.
We do not recommend setting the backlash greater than 90 arc-seconds (1.5 arc-minutes). It won't improve the life of the mechanism, and could result in chatter during machine operations.

Mount the Rotary Table

1. Prevent rust from forming on the machine table from trapped water-based coolants: put a thin film of oil (WD-40® or similar) on the surfaces.
2. Depending on your rotary table, do one of the following:
   - **Standard Rotary Table (6 in. or 8 in.)** Put the rotary table on the left side of the machine table.
   - **Super Spacer or Tilting Rotary Table (6 in. or 8 in.)** Put the rotary table on the right side of the machine table.
3. Loosely attach the rotary table toe clamps to the machine table.

> **Note:** The components are left loose so that you can adjust the rotary table.

4. Attach a magnetic dial indicator to the spindle head of the machine.
5. Put the dial indicator on the rotary table so that it will measure across the platter of the rotary table.
6. Jog the machine from side-to-side in the Y direction to indicate across the platter.
7. Use a dead blow hammer to tap the rotary table and adjust its position and reduce any misalignment determined in Step 6.
8. Completely tighten the rotary table toe clamps to secure the rotary table to the machine table.

Set Up the microARC 4

Complete the following steps in the order listed:

Required Tools **80**
Install in Machine **80**
Center the Chuck Mounting Plate **81**

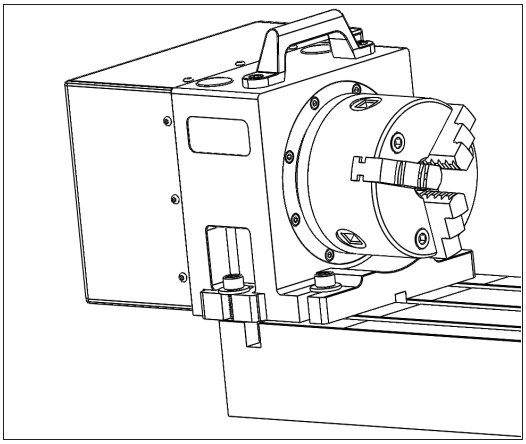
Required Tools

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

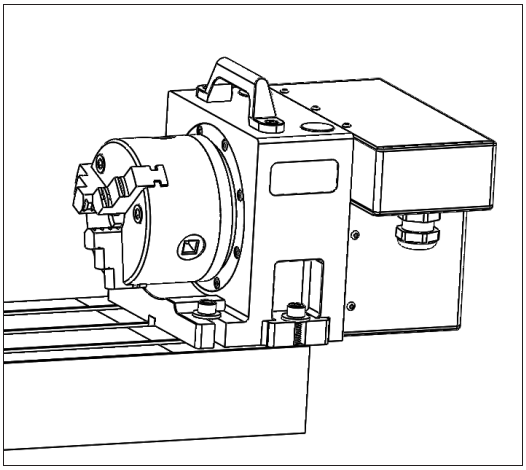
- 3 mm hex wrench
- Dead-blow hammer (or similar)
- Magnetic dial indicator

Install in Machine

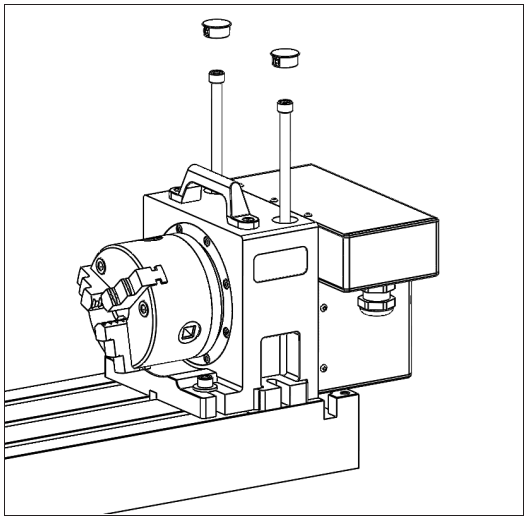
1. Put the microARC 4 on the machine table. There are several mounting configurations available, depending on the particular needs of a given project:
   a. **Left Side (Using Accessory Mounting Holes)** This configuration provides the maximum available X work space. If used with an ATC, the available 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.

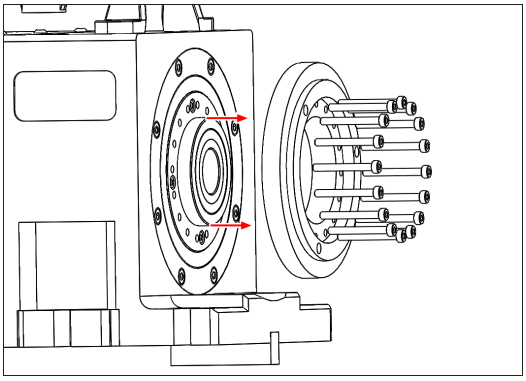


2. Feed the motor cable under the electrical cabinet and plug it into the 7-pin connector you installed with the driver kit.
3. Loosely install the 5/16" mounting bolts, using either the threaded accessory mounting holes on your machine table or T-nuts.
4. Use the key on the bottom of the 4th axis to 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.
5. Tighten the mounting hardware with a hex wrench.

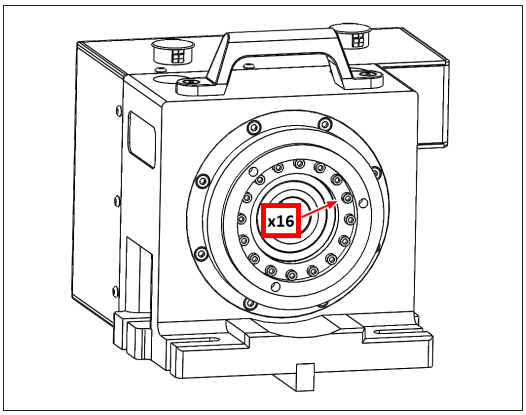
Center the Chuck Mounting Plate

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.

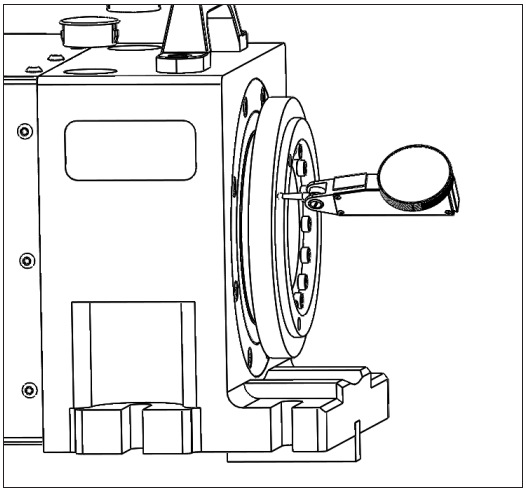
3. The mounting plate is designed for a loose fit onto the output of the harmonic drive. This allows you to adjust the center of rotation to control runout at the chuck.



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 the 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 Reset 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.

4.8.6 Install the Chip Pans

> ⚠ **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. Clean the surfaces of the chip pans and the Machine Stand with a mild degreaser (like Simple Green®) to make sure that the butyl tape bonds to the chip pans.
5. Find the roll of butyl tape that you set aside in "Assemble the Machine Stand" (page 40).
6. Remove the cover paper, and then put one strip of butyl tape along each edge on the top of the Machine Stand. Make sure that the butyl tape completely covers the space in the corners or between joints — the butyl tape should make a seal between the Machine Stand and the chip pans to help prevent leaks.

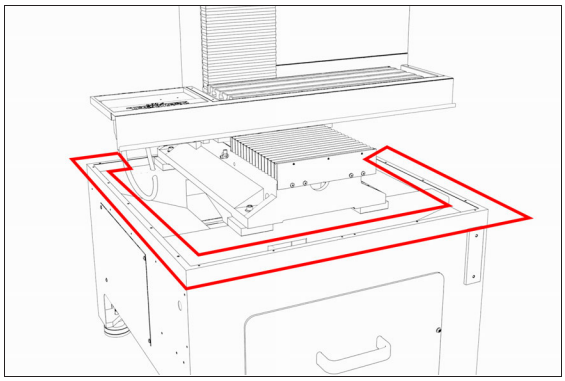


Figure 4-105: Example of the locations to put butyl tape.

7. Break the butyl tape on each screw hole on the top edge of the Machine Stand with a small hex wrench (or similar).
8. Remove the remaining cover paper from the butyl tape strips.
9. Align the right-hand chip pan with the Machine Stand.
10. Loosely attach the right-hand chip pan to the Machine Stand with a 4 mm hex wrench and seven M6 × 1.0 - 12 button head flange screws.

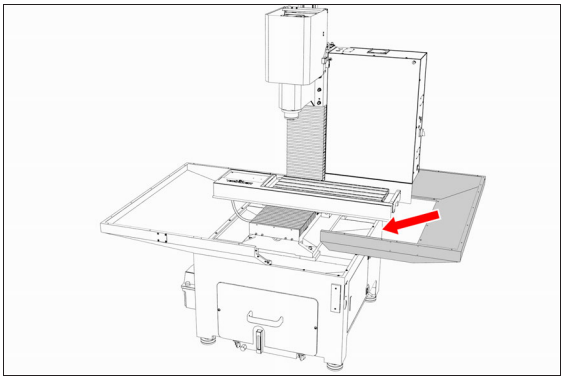


Figure 4-106: Right-hand chip pan aligned with the Machine Stand.

11. Put a strip of butyl tape along the center seam on the front of the right-hand chip pan to make a seal between the two chip pans.
12. Remove the remaining cover paper from the butyl tape strip.
13. Align the left-hand chip pan with the Machine Stand.
14. Loosely attach the left-hand chip pan to the Machine Stand with a 4 mm hex wrench and 11 M6 × 1.0 - 12 button head flange screws.

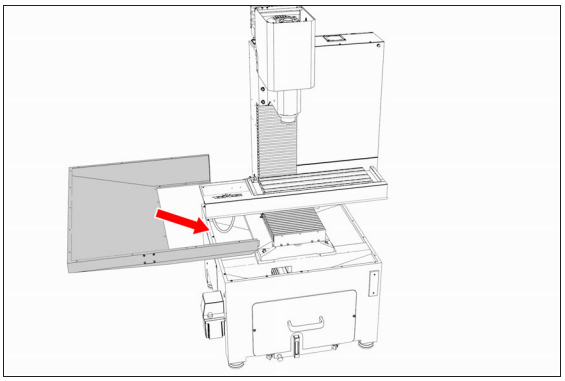


Figure 4-107: Left-hand chip pan aligned with the Machine Stand.

15. Securely tighten all screws on the chip pans until they're snug.
16. Install the Emergency Stop box to the front of the chip pan with four M5 screws.

17. Depending on your machine setup, do one of the following:
    - **Machine with Enclosure** You've completed the installation of the chip pans.
    - **Machine Without Enclosure** Find the stainless steel wear guard that you set aside earlier, and attach it across the front of the chip pans with two M5 × 0.8 - 10 button head flange screws.

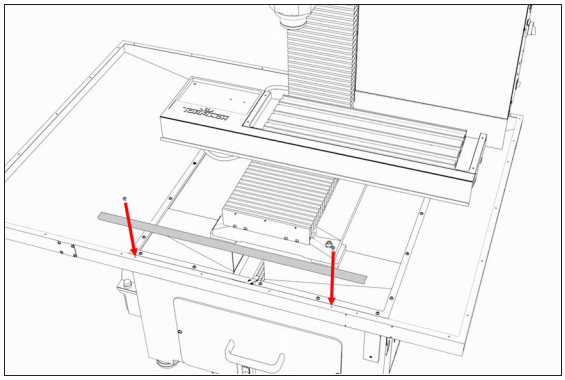


Figure 4-108: Stainless steel wear guard aligned with the front of the chip pans.

4.8.7 Install the Backsplash and Splash Guard

IMPORTANT! If you're installing an enclosure, don't install the backsplash or splash guard; you don't need them if you have an enclosure. Go to "Install the Enclosure" (below).

1. Attach the backsplash to the left-hand chip pan with a 4 mm hex wrench and two M6 × 1.0 - 12 screws.

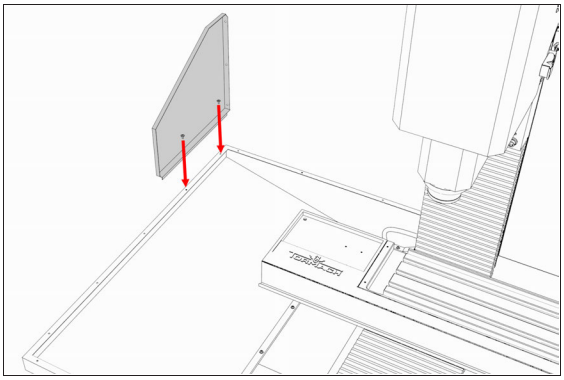


Figure 4-109: Backsplash aligned with the left-hand chip pan.

2. Attach the backsplash to the rear of the left-hand chip pan with a 4 mm hex wrench and three M6 × 1.0 - 12 screws.

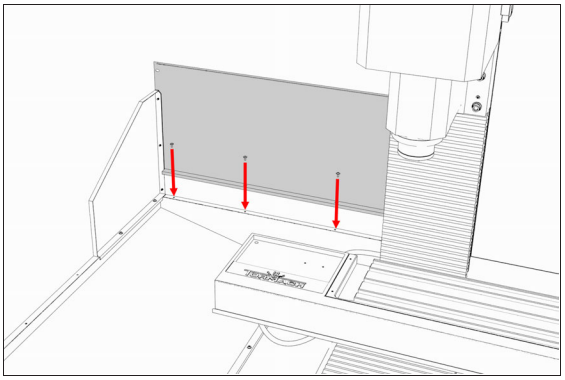


Figure 4-110: Backsplash aligned with the rear of the left-hand chip pan.

3. Connect the two backsplash panels together with a 4 mm hex wrench and three M6 × 1.0 - 12 screws.

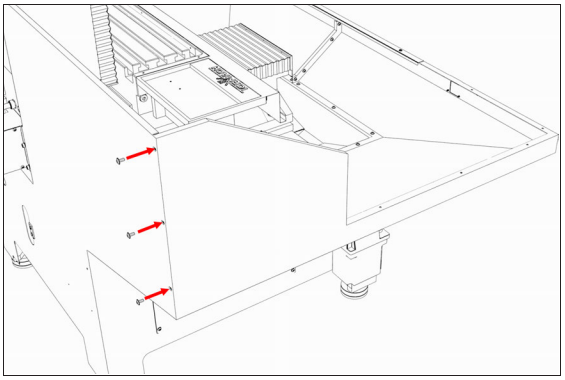


Figure 4-111: Connecting the two backsplash panels together.

4. Attach the sides of the splash guard to the splash guard connecting plate with two M5 × 20 mm screws.
5. Move the plastic splash guard between the two sides of the splash guard.
6. Remove the four set screws from the four corners of the machine table, and then discard the set screws.
7. Attach the splash guard assembly to the four corners on the machine table with the four provided socket head cap screws.

4.8.8 Install the Enclosure

Complete the following steps in the order listed:

Before You Begin **85**
Required Tools **85**
Install the Enclosure Panels **85**
Install the Left Rear Panel 85
Install the Left Side Panel 86
Install the Left Side Window Retainers 86
Install the Left Front Panel 86

Install the Enclosure Splice Plate 87
Install the Right Rear Panel 87
Install the Right Side Panel 87
Install the Right Side Window Retainers 87
Install the Right Front Panel 87
Install the Left Top Panel 88
Install the Right Top Panel 88
Install the Upper Front Panel 89
Install the Front Lower Panel 89
Install the Rear Splash Shield 89
Assemble the Linear Rails 89
Install the Linear Assemblies 90
Assemble the Front Doors 91
Install the Front Door Assemblies 91
Install the Door Latch 92
Install the Floodlights 92
Install the Side Windows 93
Install the Access Panel 94
Install the Stainless Steel Wear Guard 95
Use the Maintenance Labels 95
Write the Date on the Maintenance Labels 95
Replace the Windows 95

Before You Begin

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. Clean all chips and swarf from the:
   - Chip basket
   - Chip pans
   - Machine

> **Note:** The procedure to install the enclosure uses many screws. If you start with a clean machine, it's easier and safer to find and pick up any screws that might drop during the procedure.

4. Verify that the coolant tank and chip basket are under the Machine Stand.
5. If previously installed, you must first remove the stainless steel wear guard from the chip pans, and set it aside for later installation.

> **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

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

- Metric hex wrench set
- Permanent marker
- Shears or knife

Install the Enclosure Panels

> **Tip!** To install the enclosure panels, **work from the left to the right of the machine**.
> To make it easier to install all components, **don't install the side windows until later in the procedure**. **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.

Install the Left Rear Panel

1. Attach the column cover to the machine column with three M6 × 1.0 - 12 screws.
2. Attach the left rear panel to the column cover with four M5 × 0.8 - 10 screws.

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

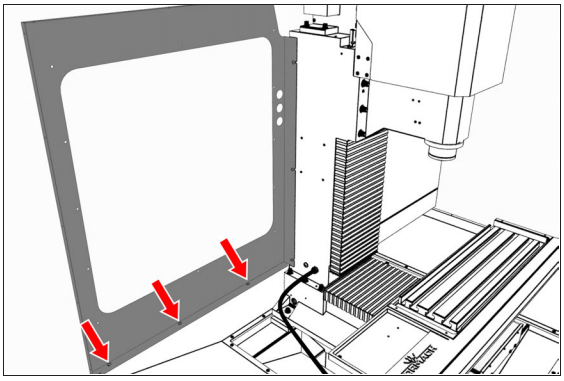


Figure 4-112: Left rear panel attached to the left chip pan.

Install the Left Side Panel

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

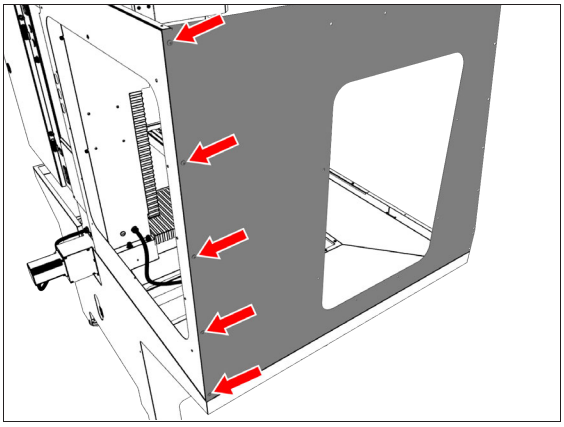


Figure 4-113: Left side panel attached to the left rear panel.

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

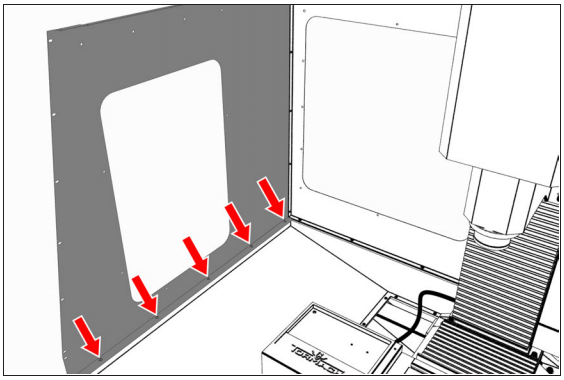


Figure 4-114: Left side panel attached to the left chip pan.

Install the Left Side Window Retainers

> **Note:** To make it easier to install all components, don't install the side windows yet. Wait until later in the procedure.

1. Push a strip of rubber window trim on to the edges of:
   - Two vertical window retainers
   - One horizontal window retainer
     When finished, use shears or a knife to cut the excess trim.
2. Loosely install two vertical window retainers on both sides of the left side panel's window opening with two sets of three M5 × 0.8 - 10 screws.
   Don't fully tighten the screws. Leaving the window retainers loose makes it easier to install the side windows.
3. Loosely attach one horizontal window retainer to the bottom of the left side panel's window opening with two M5 × 0.8 - 10 screws.

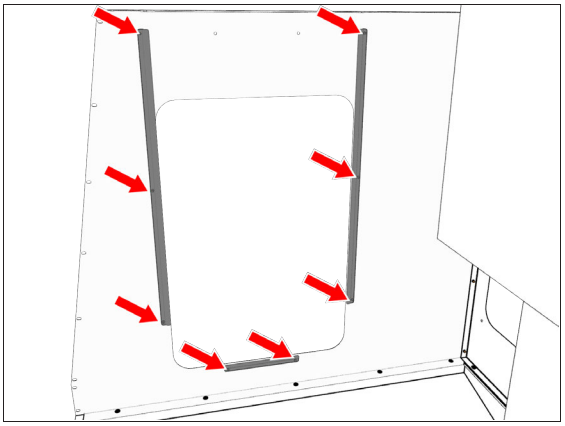


Figure 4-115: Side window retainers attached to the left side panel.

Install the Left Front Panel

1. Attach the left front panel to the left chip pan with threeM6 × 1.0 - 12 screws.

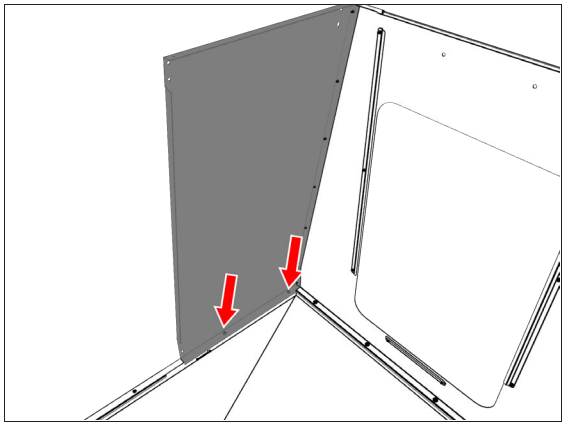


Figure 4-116: Left front panel attached to the left chip pan.

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

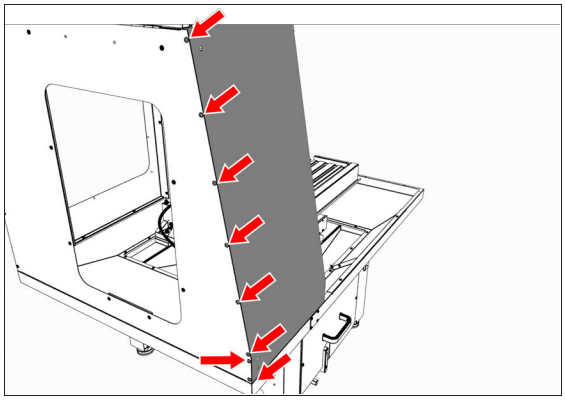


Figure 4-117: Left front panel attached to the left side panel.

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 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.
3. Attach the right rear top panel 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 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 Side Window Retainers

> **Note:** To make it easier to install all components, don't install the side windows yet. Wait until later in the procedure.

1. Push a strip of rubber window trim on to the edges of:
   - Two vertical window retainers
   - One horizontal window retainer
     When finished, use shears or a knife to cut the excess trim.
2. Loosely install two vertical window retainers on both sides of the right side panel's window opening with two sets of three M5 × 0.8 - 10 screws.
   Don't fully tighten the screws. Leaving the window retainers loose makes it easier to install the side windows.
3. Loosely attach one horizontal window retainer to the bottom of the right side panel's window opening with two M5 × 0.8 - 10 screws.

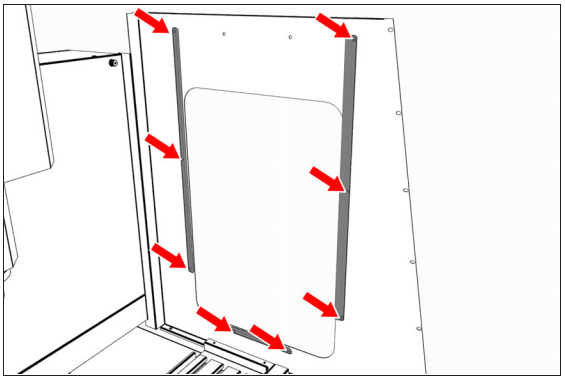


Figure 4-118: Side window retainers attached to the right side panel.

Install the Right Front Panel

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

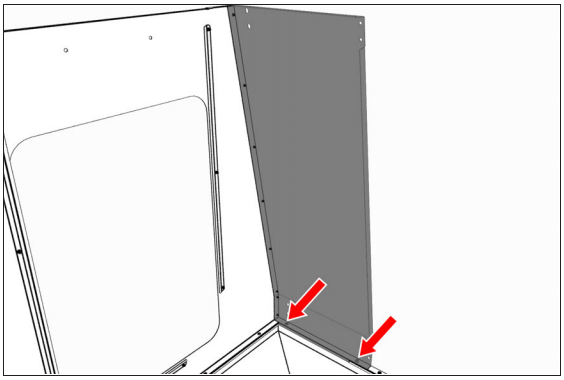


Figure 4-119: Right front panel attached to the right chip pan.

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

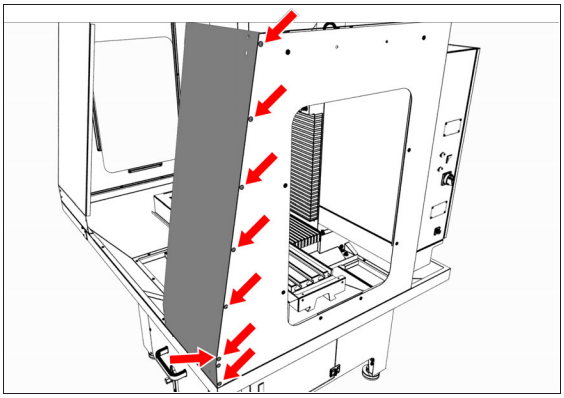


Figure 4-120: Right front panel attached to the right side panel.

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.

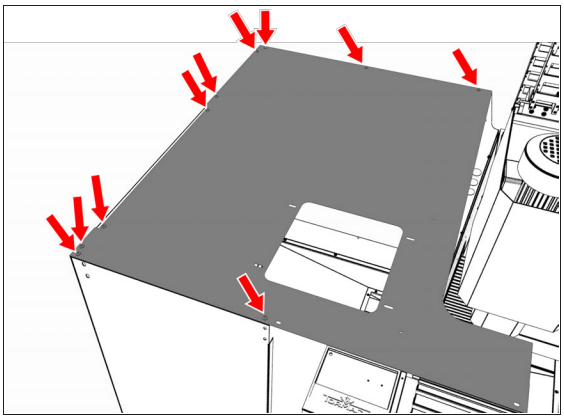


Figure 4-121: Left top panel attached to the left side of the enclosure.

2. Attach two cable tie anchors to the left top panel with two M5 × 0.8 - 10 screws.

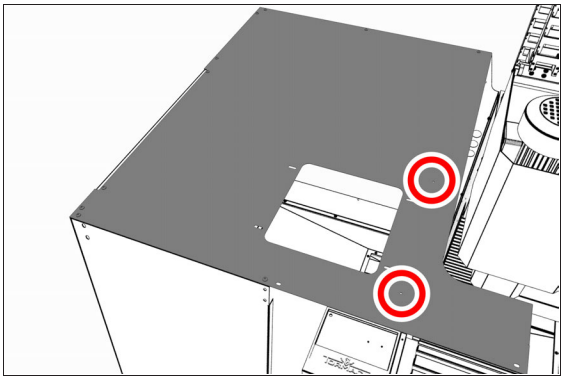


Figure 4-122: Location to attach two cable tie anchors.

Install the Right Top Panel

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

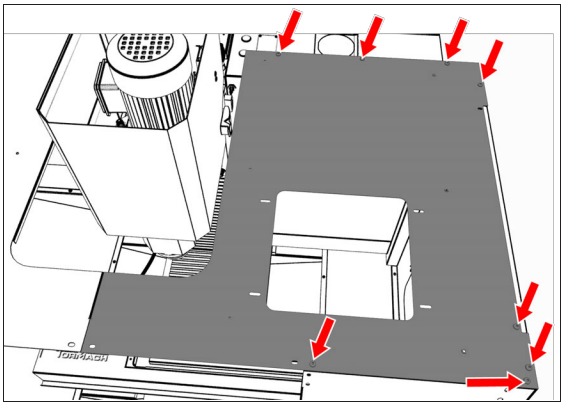


Figure 4-123: Right top panel attached to the right side of the enclosure.

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

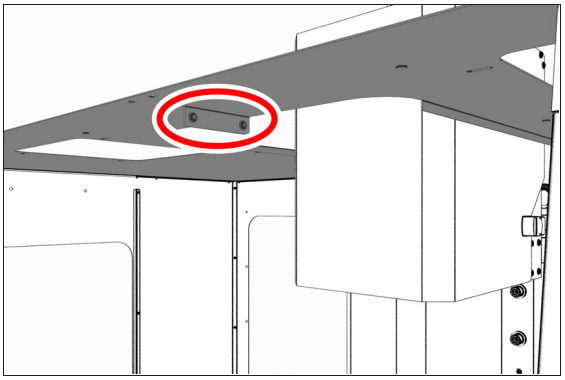


Figure 4-124: Left and right top panels connected.

3. Attach three cable tie anchors to the right top panel with three M5 × 0.8 - 10 screws.

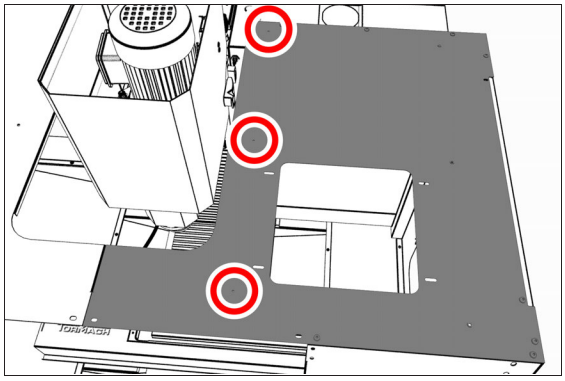


Figure 4-125: Location to attach three cable tie anchors.

Install the Upper Front Panel

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

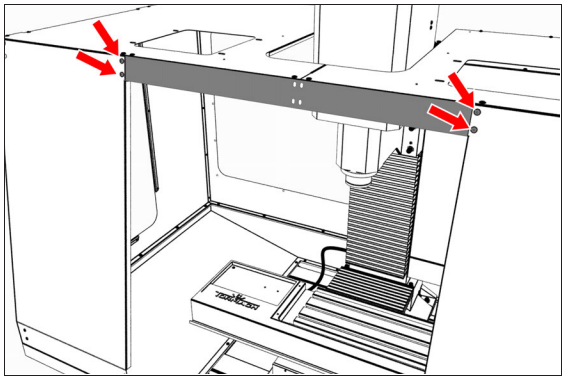


Figure 4-126: Front upper panel attached to the right and left front panels.

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

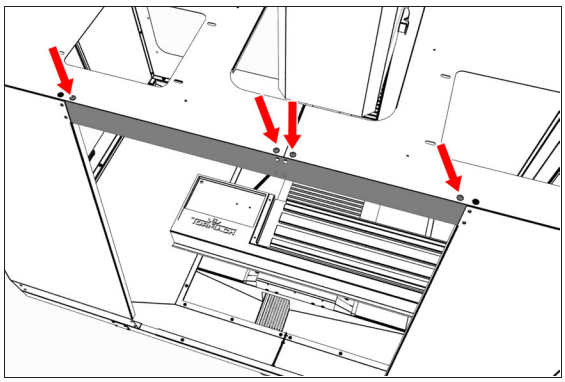


Figure 4-127: Front upper panel attached to the right and left top panels.

Install the Front Lower Panel

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

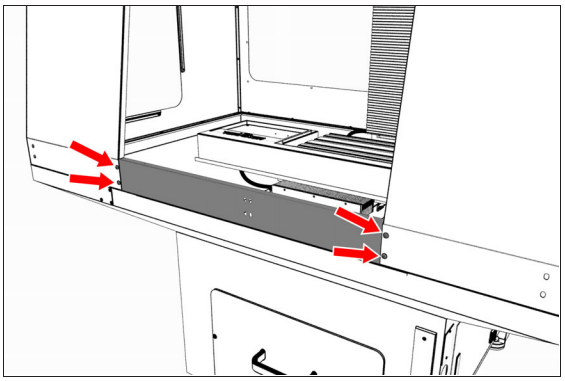


Figure 4-128: Front lower panel attached to the right and left front panels.

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

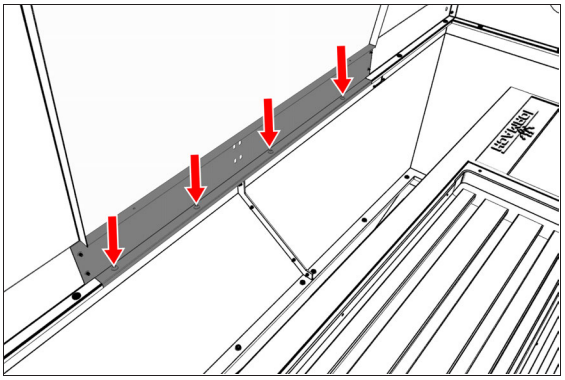


Figure 4-129: Front lower panel attached to the right and left chip pans.

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.

Assemble the Linear Rails

1. Find the four linear rails provided: use the two shorter linear rails on the right side of the enclosure. Use the two longer linear rails on the left side of the enclosure.

2. Assemble each linear rail in the following order:
   a. Slide one linear rail mount onto one end of the linear rail.
      Don't completely tighten the clamping screw on the linear rail mount. It's easier to install and align the linear rails with loose clamping screws.
   b. Slide one bumper onto the linear rail.
   c. Slide two linear bearings onto the linear rail.
   d. Slide one bumper onto the opposite end of the linear rail.
   e. Slide one linear rail mount onto the opposite end of the linear rail.
      Make sure that the linear rail mount's clamping screw faces the same direction as the linear rail mount that you installed in Step A.

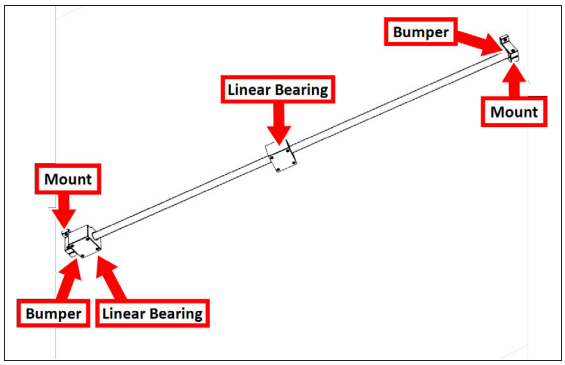


Figure 4-130: Linear rail assembly.

3. Repeat Step 2 for the remaining three linear rails.

Install the Linear Assemblies

1. Align one short linear rail assembly 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.

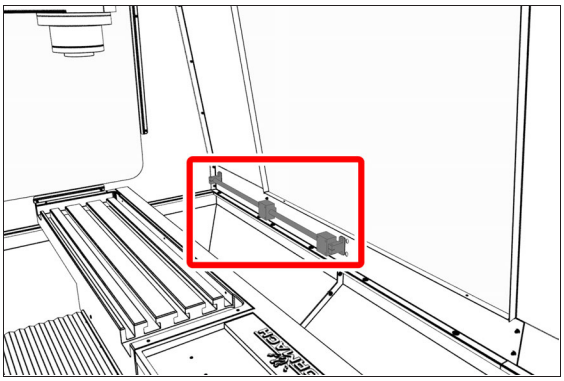


Figure 4-131: Right lower linear assembly attached to the inside of the enclosure's lower right side.

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.

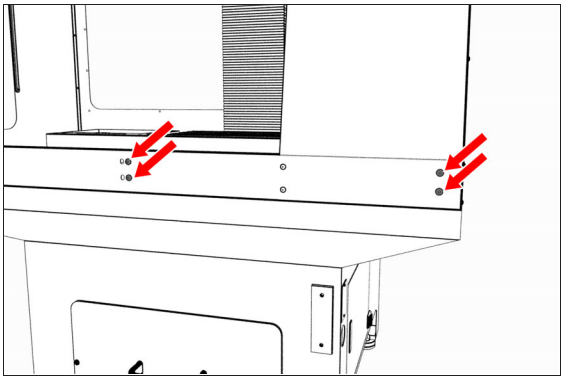


Figure 4-132: Right lower linear assembly attached to the outside of the enclosure's lower right side.

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

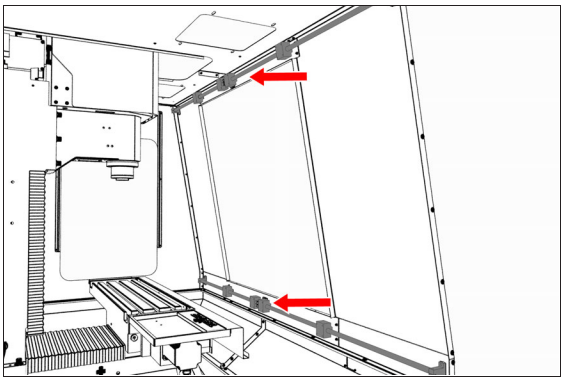


Figure 4-133: Four linear assemblies attached to the enclosure.

Assemble the Front Doors

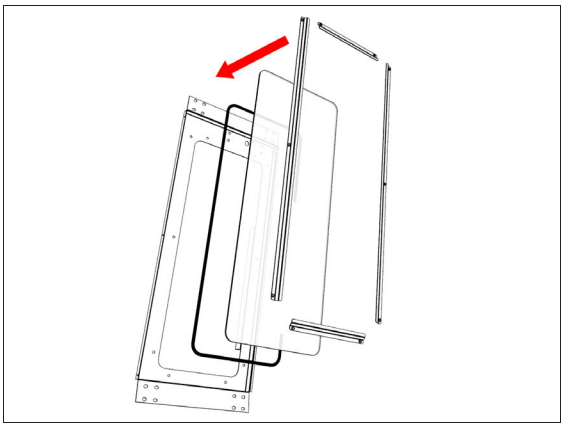


Figure 4-134: Rubber trim, window, and window retainers layered to assemble the front door.

1. Push a strip of rubber trim onto the edge of the window opening on each front door. Make sure that the trim starts at one end of the door handle mount, continues around the perimeter of the window, and ends at the opposite side of the door handle mount. When finished, use shears or a knife to cut the excess trim.
2. Remove and discard the protective plastic film from each window.
3. On the inside of one front door, put one window on top of the rubber trim.
4. Attach one dark gray, vertical window retainer to both sides of the front door's window opening with two sets of three M5 × 0.8 - 10 screws.

   > ***NOTICE!*** To prevent window damage from over-tightening, use your fingers to tighten the screws.

5. Attach one dark gray, horizontal window retainer to the top and bottom of the front door's window opening with two sets of two M5 × 0.8 - 10 screws.

   > ***NOTICE!*** To prevent window damage from over-tightening, use your fingers to tighten the screws.

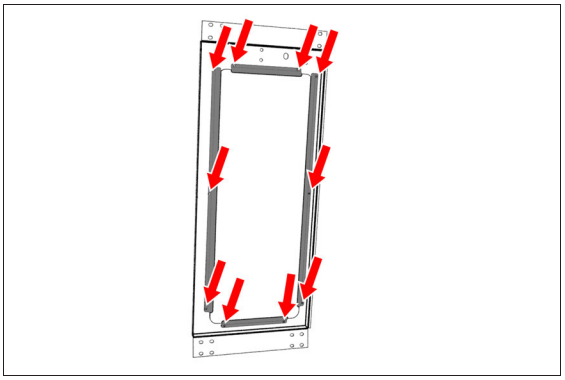


Figure 4-135: Window retainers attached to the front door.

6. Repeat Steps 1 through 5 to assemble the remaining front door.

Install the Front 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.

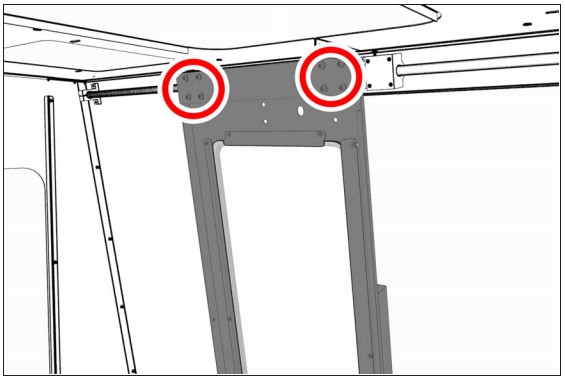


Figure 4-136: Narrow door attached to the top linear assembly.

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.

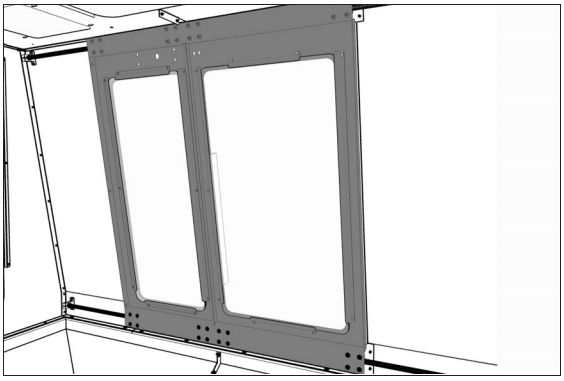


Figure 4-137: Both front doors attached to the enclosure.

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.

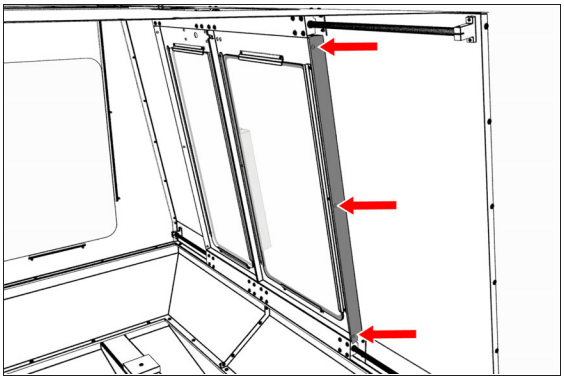


Figure 4-138: Door seal attached to the edge of the front door.

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.

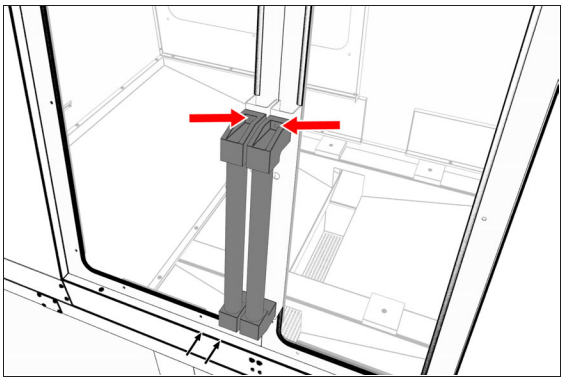


Figure 4-139: Both front door handles attached to the enclosure.

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

Install the Door Latch

1. Attach the door latch strike plate on the left front door with a Phillips screwdriver and two M3 screws.
2. Attach the door latch in the pocket on the right door with two M3 screws.

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.

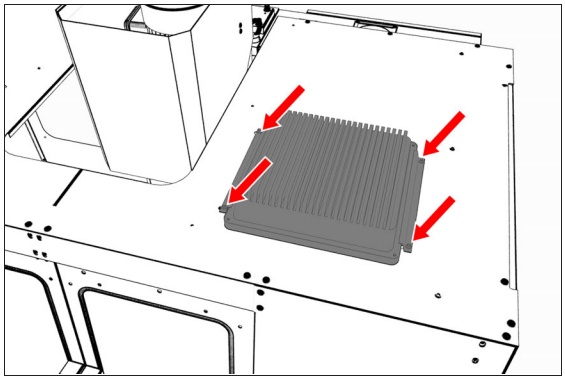


Figure 4-140: Floodlight attached to the top panel.

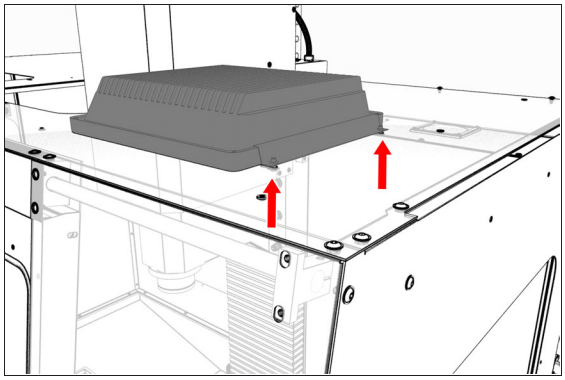


Figure 4-141: Attached floodlight from the inside of the enclosure.

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 Side Windows

1. Rubber trim is required to prevent leaks around the window openings: push a strip of rubber trim to the edge of the window opening on each side panel. Verify that the trim covers the entire perimeter of the window. When finished, use shears or a knife to cut the excess trim.

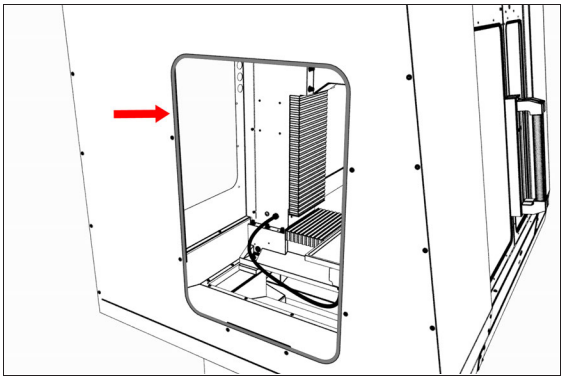


Figure 4-142: Rubber trim pushed onto the window opening.

2. Remove and discard the protective plastic film from the windows.
3. Slowly slide one window through the left top panel's window opening and into the two installed vertical window retainers. Take care to not scratch the window. When finished, verify that the window rests on the bottom horizontal window retainer.

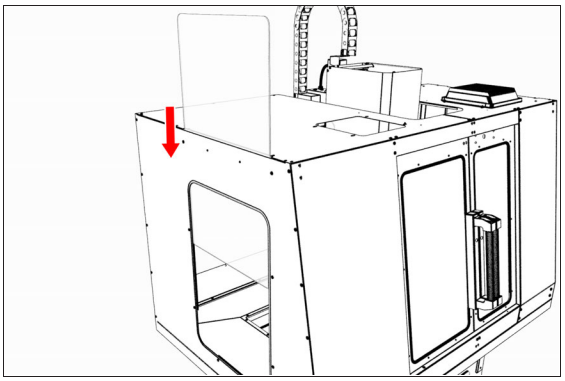


Figure 4-143: Window sliding into the window opening.

4. Push a strip of rubber trim onto the edge of one horizontal window retainer. When finished, use shears or a knife to cut the excess trim.

5. Attach one horizontal window retainer above the window on the left side panel with two M5 × 0.8 - 10 screws.

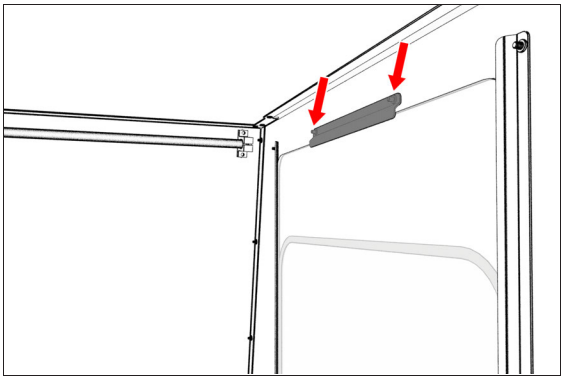


Figure 4-144: Horizontal window retainer attached above the window.

6. Tighten all screws on the window retainers to secure the window.

> ***NOTICE!*** To prevent window damage from over-tightening, use your fingers to tighten the screws.

7. Repeat Steps 1 through 6 for the window on the right side panel.

Install the Access Panel

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

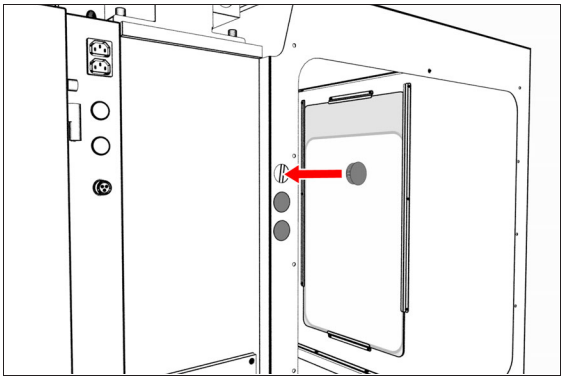


Figure 4-145: Round hole plugs pushed into the left rear panel.

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.

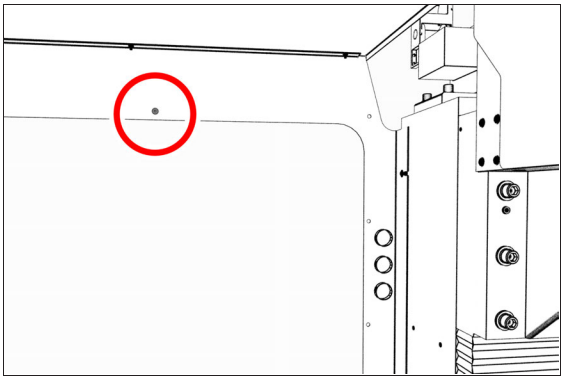


Figure 4-146: Supporting screw inside the left rear panel.

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.

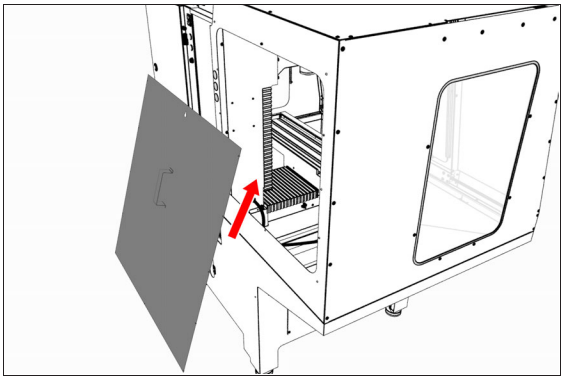


Figure 4-147: Access panel moving inside the enclosure.

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

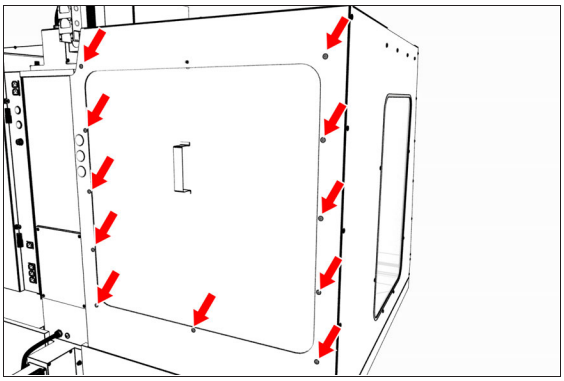


Figure 4-148: Access panel attached to the left rear panel.

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.

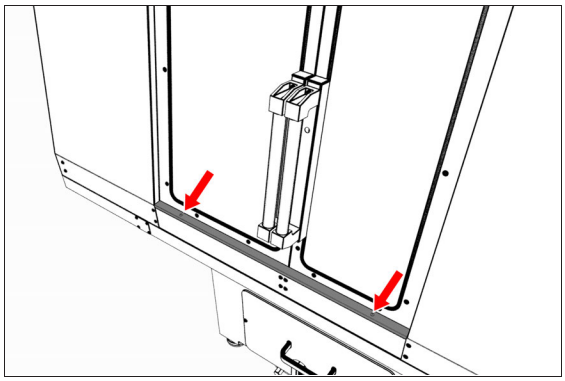


Figure 4-149: Stainless steel wear guard attached to the lower front panel.

Use the Maintenance Labels

Write the Date on the Maintenance Labels

The machine has one maintenance label on each window.

Figure 4-150: Window maintenance label.

➢ Write down today's date on each label with a permanent marker.
You have completed assembling and installing the 770M 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)

4.8.9 Set up the Door Lock Switch Kit (Optional)

The Door Lock Switch Kit (PN 38283) is an **optional accessory** that reduces risk by allowing you to lock enclosure doors during potentially hazardous machining operations.
Complete the following steps in the order listed:

Install the Door Lock Switch Kit **95**
Update PathPilot **97**
Enable the Door Lock Switch Kit **98**

Install the Door Lock Switch Kit

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. Attach the door switch to the door switch installation plate on the right enclosure door with a 3 mm hex wrench and four M5 × 0.8-50 button head screws.

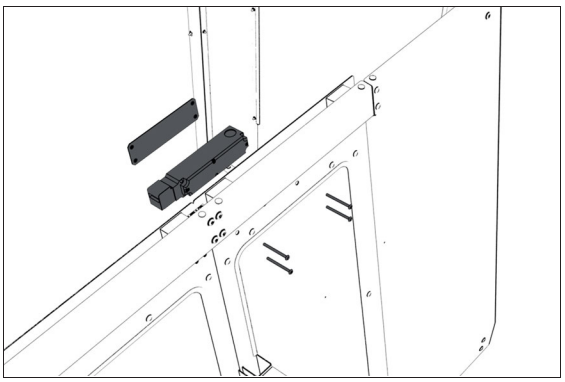


Figure 4-151: Attaching the door switch assembly to the right side of the enclosure.

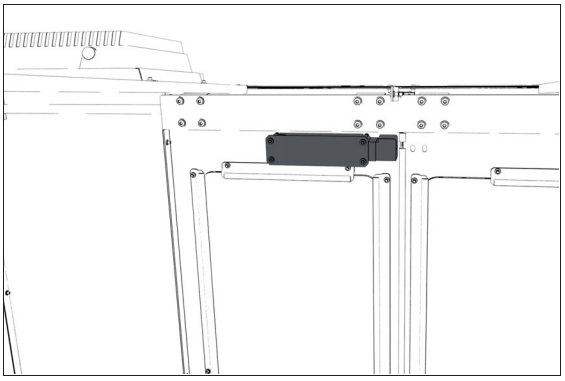


Figure 4-152: Door switch assembly attached. (Viewed from inside the enclosure.)

3. Loosely attach the lock key and the lock key nut to the lock key bracket with a 3 mm hex wrench and two M5 × 0.8-10 flanged button head screws. You'll make further adjustments later in this procedure.

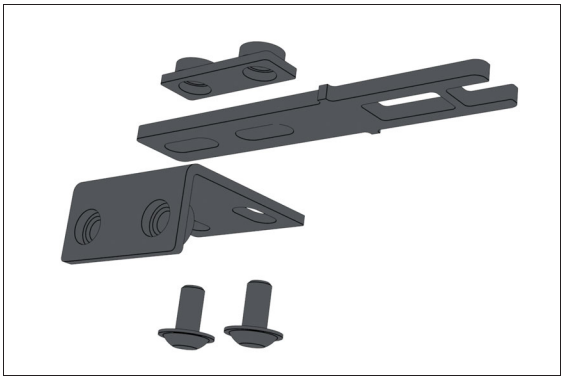


Figure 4-153: Attaching the components of the lock key bracket assembly.

4. Loosely attach the lock key bracket assembly to the left enclosure door with a 3 mm hex wrench and two M5 × 0.8-10 flanged button head screws. You'll make further adjustments later in this procedure.

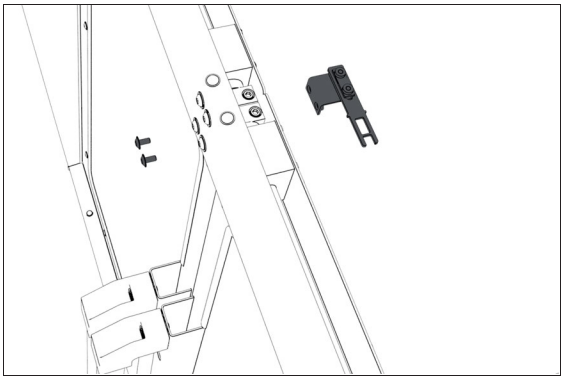


Figure 4-154: Attaching the lock key bracket assembly to the left side of the enclosure.

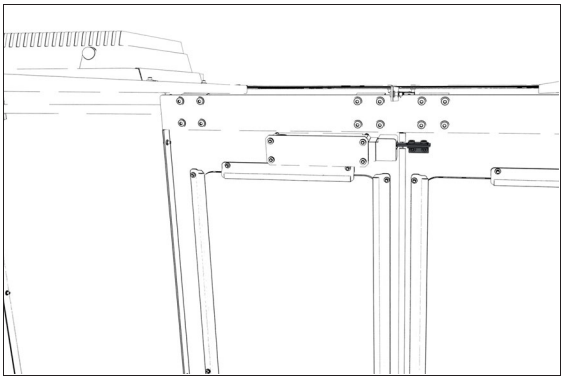


Figure 4-155: Lock key bracket attached. (Viewed from inside the enclosure.)

5. Identify the door lock override switch, as shown in the following image.

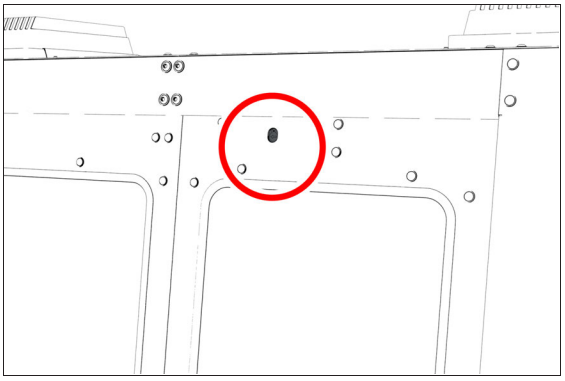


Figure 4-156: Door lock override switch.

6. Remove the screw that secures the door lock override switch with a Phillips screwdriver, and then set it aside.
7. Turn the door lock override switch to the unlocked position with a flat-blade screwdriver.
8. Open and close the enclosure doors to align the door switch and the lock key. Make sure that the lock key freely engages and disengages the door switch.
9. Tighten all four M5 × 0.8-10 flanged button head screws on the lock key assembly.
10. Attach two cable tie anchors to the right top panel on the enclosure with a 3 mm hex wrench and three M5 × 0.8-10 flanged button head screws.

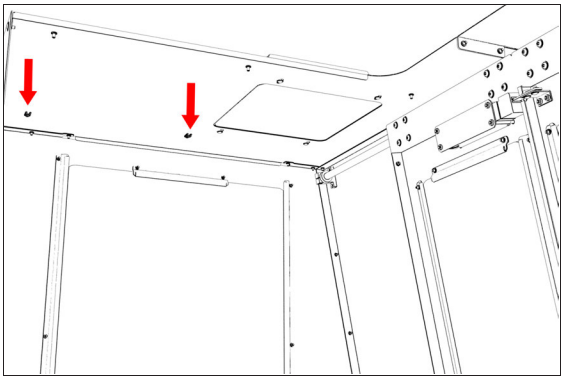


Figure 4-157: Cable tie anchors installed inside the right side of the enclosure.

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Specifications subject to change without notice.

11. Attach the remaining cable tie anchor to the enclosure light's screw, as shown in the following image.

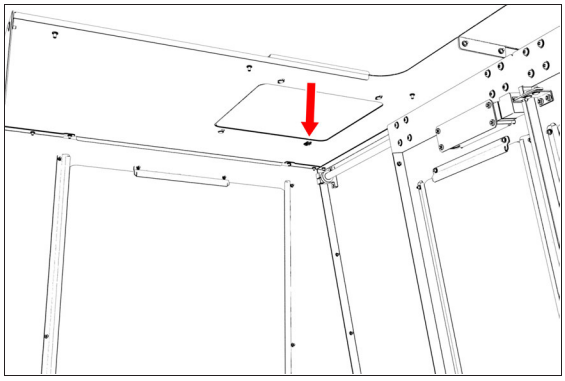


Figure 4-158: Cable tie anchor installed on the enclosure light's screw.

12. Route the loose end of the door switch cable to the electrical cabinet, and connect it to the Enclosure Door Switch outlet.
13. Secure the door switch cable to the cable tie anchors that you installed with three cable ties. Make sure that the cable doesn't restrict the motion of the enclosure door. Wind any remaining cable in to a coil, and secure it to the cable tie anchor closest to the Enclosure Door Switch outlet.

Figure 4-159: Cable routing from the enclosure light to the door, without interference.

14. Turn the door lock override switch to the locked position with a flat-blade screwdriver.
15. Find the screw for the door lock override switch that you set aside in Step 6. Then, put it back to secure the door lock override switch in the locked position.
16. 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 Reset button.
    d. Bring the machine out of reset and reference it.

Update PathPilot

Before using the Door Lock Switch Kit, you must make sure that the PathPilot controller is updated to PathPilot v2.1.6 (or newer). This version of PathPilot has settings required to use the Door Lock Switch Kit.
To update PathPilot, do either of the following:

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

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. Then, select **Update**.

Figure 4-160: Update button on the Status tab.

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

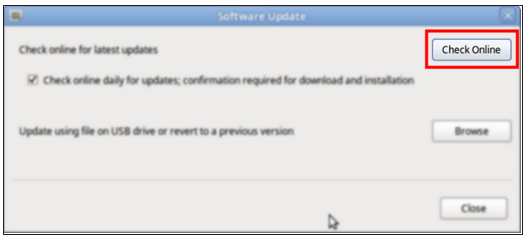


Figure 4-161: Software Update dialog box.

4. Select **Install**.

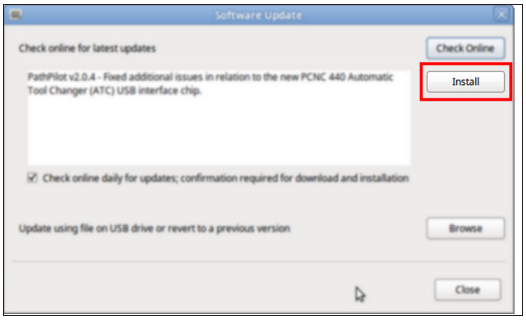


Figure 4-162: Install button on the Software Update dialog box.

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.

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 4-163: Update button on the Status tab.

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

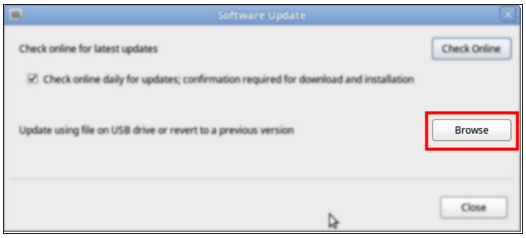


Figure 4-164: Software Update dialog box.

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

Figure 4-165: 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.

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**.

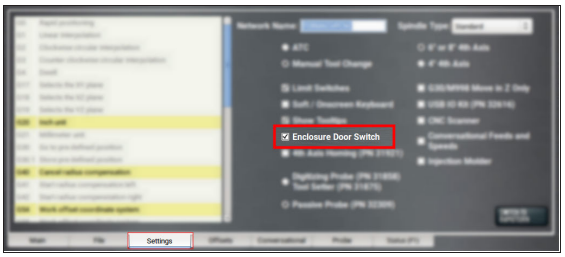


Figure 4-166: Settings tab.

On the **Status** tab, the **Door Locked / Open** LEDs display.

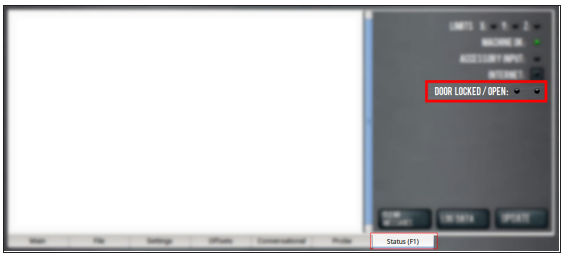


Figure 4-167: Status tab.

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 4-168: Door Open LED on the Status tab.

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.

4.8.10 Install the PathPilot Operator Console

Complete the following steps in the order listed:

Required Tools **99**
Prepare the Machine **99**
Remove the Right Side Window 99
Remove the Operator Box 99
Install the Mount Arm **99**
Mount the Console **101**
Assemble the Controller and Keyboard Tray 101
Lift and Secure the Controller Assembly 102
Make Electrical Connections **103**
Reassemble the Machine **105**
PathPilot Operator Console Drill Template **106**

Required Tools

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

- 15/64 in. drill bit
- Electric drill
- Hole punch
- Level
- Metric hex wrench set
- Phillips screwdriver
- Phillips screwdriver, small
- Scissors
- Ruler
- Tape

Prepare the Machine

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. Close the enclosure doors.

> ***NOTICE!*** This procedure requires you to drill four holes into the enclosure. If the enclosure's right door is open, there's a risk that you'll drill into it.

Remove the Right Side Window

➢ To make it easier to install the mount arm, we recommend removing the right side window from the enclosure. Loosen the screws on the vertical window retainers, and slide the window out of the right side panel. Set the window aside.

Remove the Operator Box

1. Remove the Emergency Stop cable from the operator box.
2. Remove the four screws that secure the operator box to the machine stand using a 3 mm hex wrench.
   Discard the operator box.
3. Put the four screws from the operator box back on to the machine stand.

Install the Mount Arm

1. Print the drill template provided in this document. To verify that the template printed at the correct size, use a ruler to measure the 1 in. scale on the template. If the template is incorrectly sized, adjust your printer settings and try again.
2. Cut out the drill template along its edges.
3. Find the operator console's mount arm.

4. Put the drill template on the mount arm's top bracket. Then, verify that the holes on the bracket align with the holes on the drill template. If they don't, trace the correct hole pattern on to the drill template.
5. Align the drill template to the top of the enclosure and tape it in place, as shown in the following image.

Figure 4-169: Drill template taped to the enclosure.

6. Put a mark in each hole on the drill template using a hole punch.
7. Remove the drill template from the enclosure and discard it.
8. Drill into the marks on the enclosure that you made in Step 6 using an electric drill and a 15/64 in. (6 mm) drill bit.

Figure 4-170: Drilling holes into the top of the enclosure.

9. Loosely secure the top of the mount arm to the enclosure with four M5 × 0.8 - 10 screws and washers.

Figure 4-171: Securing the top of the mount arm to the enclosure.

10. Using a level, align the bottom of the mount arm with the bottom of the enclosure.

Figure 4-172: Bottom of the mount arm level on the enclosure.

11. Using the bottom of the mount arm as a template, drill one hole using an electric drill and a 15/64 in. drill bit.
12. Put one M5 × 0.8 - 10 screw and washer into the hole that you drilled in Step 11.
    The mount arm is now secure enough to reliably drill the remaining three holes.

13. Drill the remaining three holes for the mount arm's bottom bracket.

Figure 4-173: Drilling the remaining three holes into the enclosure.

14. Put three M5 × 0.8 - 10 screws and washers into the remaining three holes.
15. Once the mount arm is secured to the enclosure, open the enclosure door and verify that the mount arm's screws don't interfere with the enclosure door jamb. If they do, loosen the screws on the door jamb, and slide it toward the back of the machine.

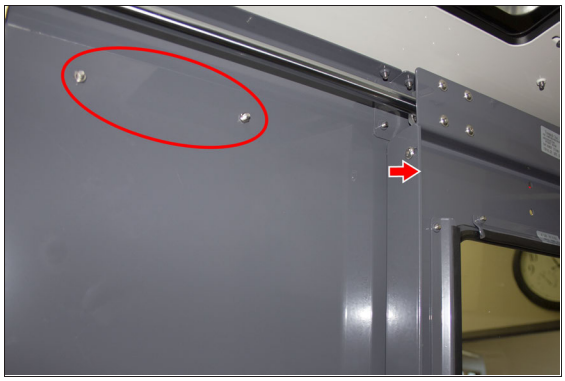


Figure 4-174: Door jamb moved to provide clearance for the mount arm's screws.

Mount the Console

Complete the following steps in the order listed:

Assemble the Controller and Keyboard Tray

1. Find the three provided split collars. If they're connected, remove their bolts using a 8 mm hex wrench, and separate them. The split collars are matched pairs, so you must keep them together.

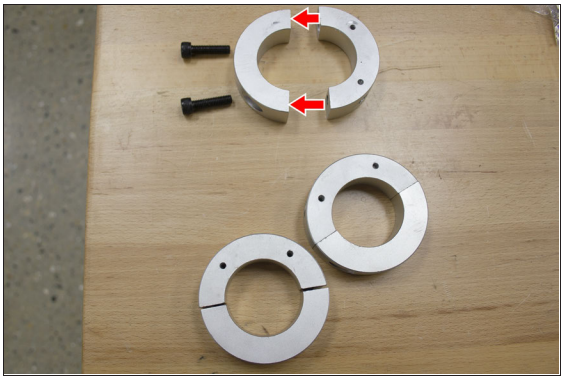


Figure 4-175: One split collar disassembled.

2. Find the four provided pieces of plastic with adhesive backing. Cut each piece of plastic so that it's the length of the inside of the split collar.
3. Adhere one piece of plastic to the inside of each split collar.

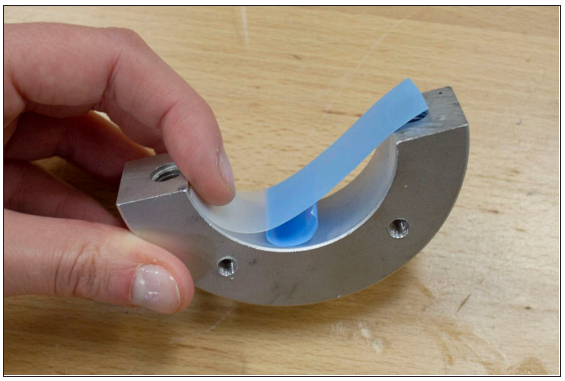


Figure 4-176: Adhering tape on the inside of a split collar.

4. Remove the operator console out of its packaging.
5. Find the three provided mount arm brackets.

Figure 4-177: Mount arm brackets.

6. Loosely attach two of the mount arm brackets to the left side of the controller with four M4 × 0.7 - 10 screws using a 2.5 mm hex wrench, as shown in the following image. Verify that the curved edge is facing away from the controller.

> **Note:** Don't completely tighten the brackets to the controller. You'll adjust them when you're adjusting the height of the entire console assembly.

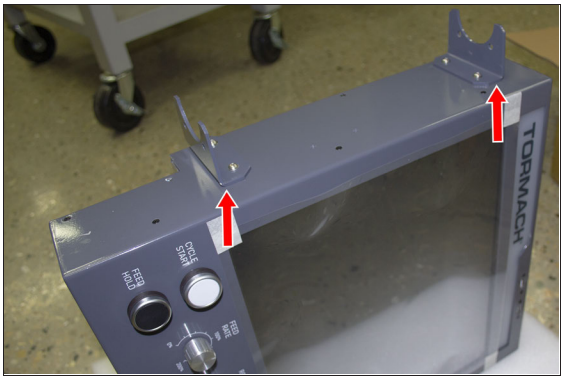


Figure 4-178: Two mount brackets attached to the controller.

7. Attach the threaded side of two split collars to the mount arm brackets with four M5 × 0.8 - 10 screws and washers.

Figure 4-179: Split collars attached to the mount arm brackets on the controller.

8. Find the keyboard tray provided. Then, attach the remaining mount arm bracket to the left side of the keyboard tray with two M4 × 0.7 - 10 screws using a 2.5 mm hex wrench. Verify that the curved edge is facing away from the keyboard tray.
9. Attach one side of one split collar to the mount arm bracket with two M5 × 0.8 - 10 screws and washers.

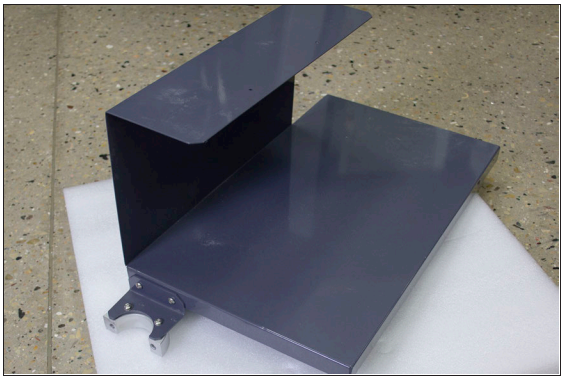


Figure 4-180: Split collar attached to the mount arm bracket on the keyboard tray.

10. Find the provided jog pendant bracket. Then, attach it to the left side of the controller (between the two mount arm brackets) with two M4 × 0.7 - 10 screws using a 2.5 mm hex wrench.
11. Set the keyboard tray aside.

Lift and Secure the Controller Assembly

1. Attach the remaining split collar to the mount arm, and completely tighten it using a 8 mm hex wrench. This split collar determines the height for the overall console assembly, so we suggest attaching it 16 in. (41 cm) from the top of the enclosure.

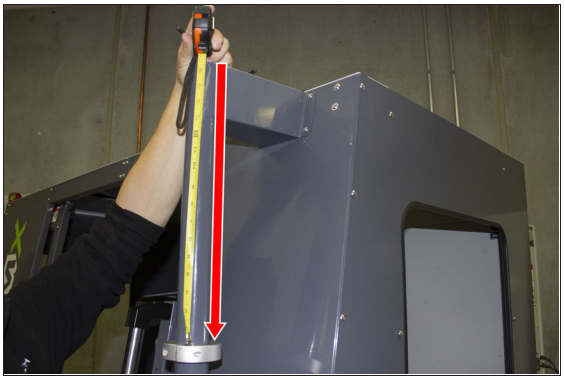


Figure 4-181: Split collar attached to the mount arm.

> **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.

2. Lift the console and hold it on the right side of the mount arm.
3. Align the bottom split collar on the controller with the split collar that you installed on the mount arm in Step 1.

4. With the aid of another person, loosely attach the opposite side of both split collars to the mount arm using a 8 mm hex wrench.

Figure 4-182: Loosely attaching the split collars to the mount arm.

5. Find the keyboard tray that you set aside earlier. Then, attach it to the bottom of the controller, as shown in the following image.

Figure 4-183: Attaching the keyboard tray to the bottom of the controller.

6. Loosely attach the opposite side of the split collar to the mounting arm using a 8 mm hex wrench.
7. Adjust the height and the angle of the console assembly as required.
8. Securely tighten all four split collars using a 8 mm hex wrench. Securely tighten all mount arm brackets using a 2.5 mm hex wrench.

Make Electrical Connections

1. Find the provided Jog Pendant (PN 50363).
2. Hang the jog pendant on its bracket (on the front of the controller) as shown in the following image.

Figure 4-184: Jog pendant on the front of the console assembly.

3. Route the loose end of the jog pendant to the back of the controller.
4. Find the provided power supply bracket. Then, attach it to the back of the controller with two M3 screws using a Phillips screwdriver.
5. Find the provided power, Ethernet, emergency stop extension, and ATC USB extension cables, and the WiFi dongle. Then, connect them – and the jog pendant cable – to the controller as shown in the following image.

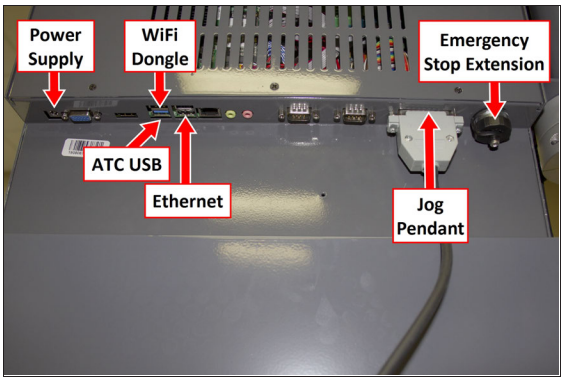


Figure 4-185: Controller connections.

6. Put the power supply into the power supply bracket.
7. Find the provided corrugated tubing and piece of rubber.

8. Attach the piece of rubber to the bracket on the rear of the keyboard tray as shown in the following image.

Figure 4-186: Rubber attached to the bracket on the keyboard tray.

9. Put the loose ends of all cables from the controller into the corrugated tubing.
10. Push the corrugated tubing into the bracket on the rear of the keyboard tray.

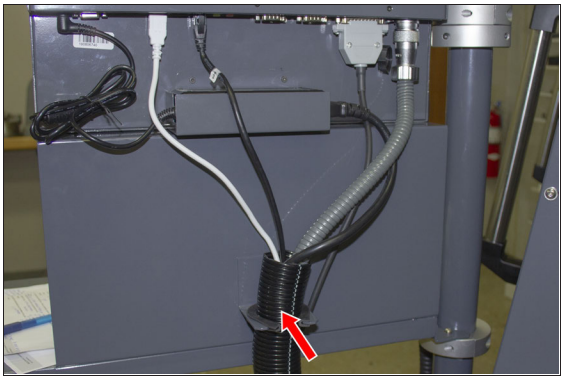


Figure 4-187: Cords put into corrugated tubing, which is attached to the rear of the keyboard tray.

11. Find the access panel on the machine stand as shown in the following image.

Figure 4-188: Access panel on the machine stand.

12. Remove the access panel using a 2 mm hex wrench, and discard the panel. Set the screws aside for later in this procedure.
13. Find the provided access panel. Then, put the loose end of the corrugated tubing and all cords through it as shown in the following image.

Figure 4-189: Loose end of corrugated tubing and all cords put through the access panel.

14. Attach the access panel – with the corrugated tubing and all cords – to the machine stand with the screws that you set aside in Step 12 using a 2 mm hex wrench.

Figure 4-190: Access panel attached to the machine stand.

15. Route the loose end of all cords through the machine stand and out toward the rear of the machine.

16. Find the existing operator box cable that's preinstalled on the machine. Then, route it through the access hole in the machine stand shown in the following image.

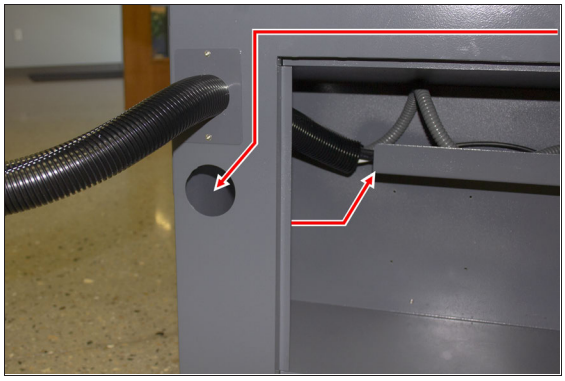


Figure 4-191: Preinstalled operator box cable routing.

17. Connect the operator box extension cable to the existing operator box cable (that you just routed into the machine stand).
18. Connect the Ethernet cable to the Controller Communications port on the side of the electrical cabinet.
19. Connect the power cable to the Accessory Power port on the rear of the electrical cabinet.
20. From the ATC, remove and discard the existing USB cable. Then, route the loose end of the ATC USB extension cable from the controller to the ATC, and connect it in place of the original USB cable.
21. If you have an EU model of the operator console, find the provided set of keys, and put it into the top of the operator console.

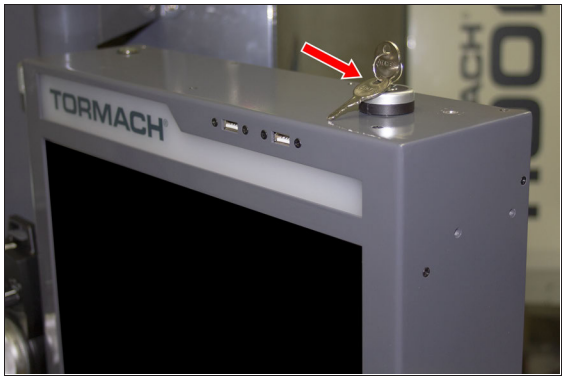
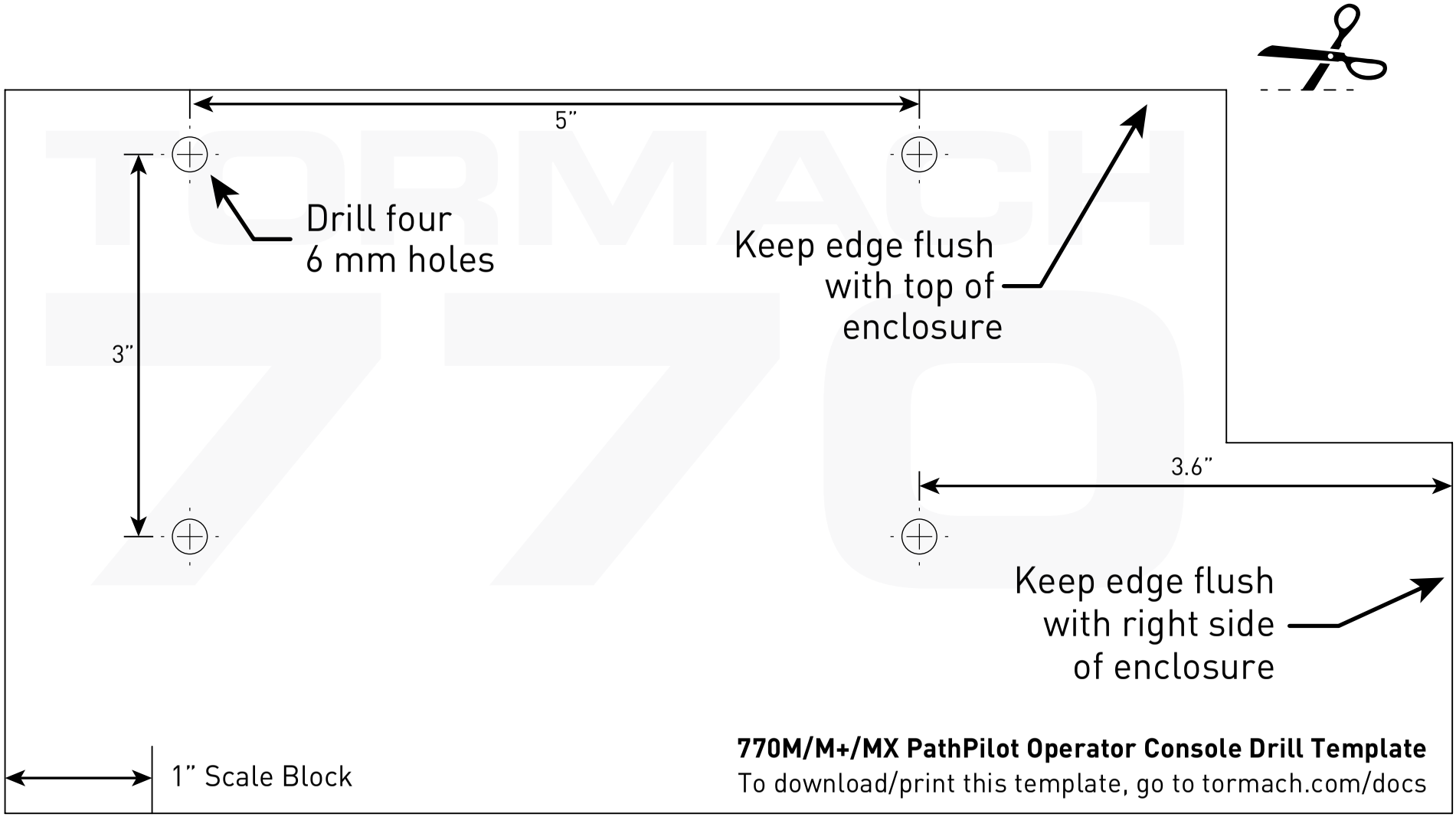


Figure 4-192: Key put into the controller.

> **Note:** On EU machines, the keys switch between run mode and setup mode. If you don't have an EU machine, you don't need the keys. For more information on operation modes, refer to the Safety section of the EU machine operator's manual.

Reassemble the Machine

1. Put the right side window (that you set aside in "Prepare the Machine" (page 99)) back into the right side panel on the enclosure. Then, tighten the screws on the vertical window retainers
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 Reset button.
   d. Bring the machine out of reset and reference it.



770M/M+/MX PathPilot Operator Console Drill Template

To download/print this template, go to tormach.com/docs

4.9 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).

4.9.1 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.
2. Complete the fields in the **Time and Date Settings** dialog box, and then select **Close**.

4.9.2 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**.

4.9.3 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.

4.9.4 Update PathPilot

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

- From the **Status** tab, select **Update**.

DRMACH

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 **110**
5.2 Basic Controls Reference **110**

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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" × 8" (660 mm × 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 an R8 taper to hold Tormach Tooling System (TTS) tool holders.

- **Spindle Power** 1.5 hp (1.1 kW)

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.
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.

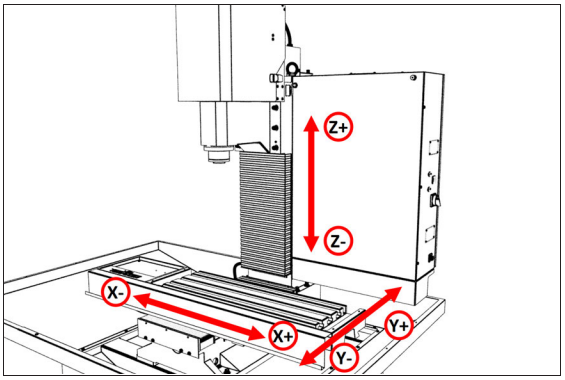

Figure 5-1: Axis directions on the machine.

Each axis has a different limit of travel, which is the distance it moves before reaching a limit switch:

- **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 operator box — which contains 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 blue 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 one of the following:

- Controller Arm
  - Controller
  - *(Optional)* Jog Shuttle
  - Keyboard
  - Monitor or *(Optional)*Touch Screen Kit
  - Mouse
- Operator Console
  - Console (with integrated touch screen)
  - *(Optional)* Keyboard
  - *(Optional)* Mouse
  - Jog pendant

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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 **114**
6.2 Notebook Section **114**
6.3 Persistent Controls **116**
6.4 Keyboard Shortcuts **117**
6.5 Manage PathPilot Versions **117**

6: PATHPILOT INTERFACE OVERVIEW

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.

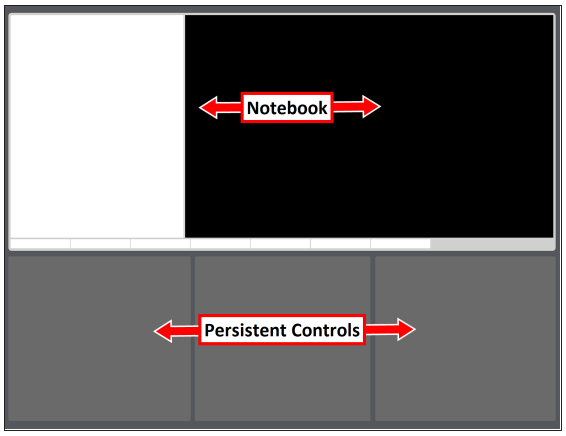

Figure 6-1: Sections in the PathPilot interface.

6.2 NOTEBOOK SECTION

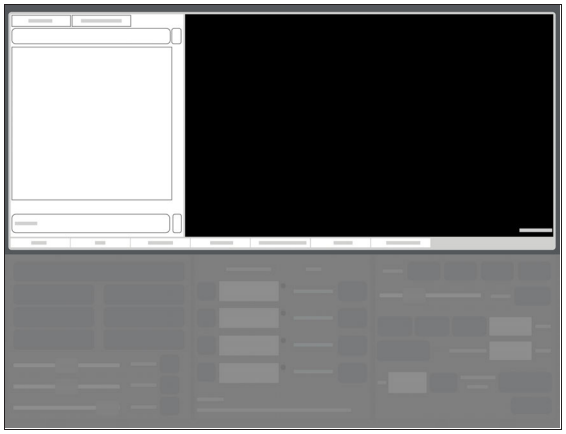

Figure 6-2: Notebook section.

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 **114**
6.2.2 File Tab **114**
6.2.3 Settings Tab **115**
6.2.4 Offsets Tab **115**
6.2.5 Conversational Tab **115**
6.2.6 Probe Tab **116**
6.2.7 Status Tab **116**

6.2.1 Main Tab

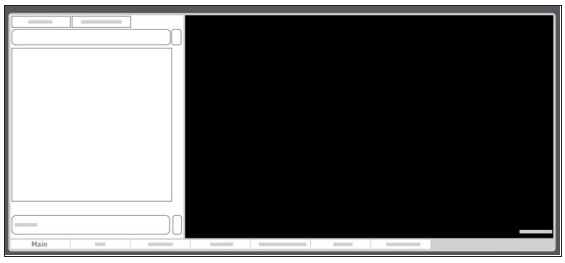

Figure 6-3: Main tab.

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 123); "Close the Current Program" (page 123).
- Send G-code commands directly to the machine using the Manual Data Input (MDI) Line DRO field.
  For information, see "Manually Enter Commands" (page 163).
- 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 124); "Expand the G-Code Tab" (page 124); "Change the View of the Tool Path Display" (page 126).

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 122).
- Edit G-code files.
  For information, see "Edit G-Code" (page 123).
- Load .nc files into PathPilot to run a program.
  For information, see "Load G-Code" (page 177).

- Move files within the system.
  For information, see "Preview G-Code Files" (page 122); "Manage System Files" (page 168).

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 140).
- Change the screen's layout orientation (landscape or portrait).
  For information, see "Change the Screen Orientation" (page 140).
- Configure PathPilot for the accessories you're using.
  For information, see "Enable the On-Screen Keyboard" (page 143); "Enable the USB M-Code I/O Interface Kit" (page 144); "Use a USB Camera" (page 146); "Specify the Tool Change Method" (page 142); "Select the Spindle Type" (page 140).
- Turn on feeds and speeds suggestions when using conversational programming.
  For information, see "Enable Feeds and Speeds Suggestions in Conversational Routines" (page 145).
- Disable the limit switches or hard stop referencing for troubleshooting.
  For information, see "Disable Limit Switches" (page 142).
- Specify the way in which you want to use a G30 move.
  For information, see "Limit G30 Moves" (page 143).
- Identify the available G-code modes that you can use.
  For information, see "View Available G-Code Modes" (page 155).

6.2.4 Offsets Tab

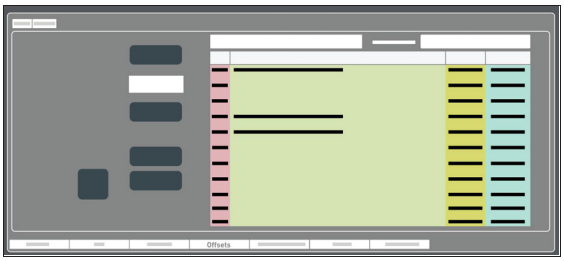

Figure 6-6: Offsets tab.

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

- Make and restore backup files of your settings.
  For information, see "Create Backup Files" (page 168); "Restore Backup Files" (page 169).
- Import and export .csv files of your tool table.
  For information, see "Import and Export the Tool Table" (page 170).
- Work with a table of tool descriptions and tool offsets.
  For information, see "Set Tool Length Offsets" (page 178).
- Use an Electronic Tool Setter (ETS) to measure tools.
  For information, see "Use an Electronic Tool Setter (ETS) to Measure Tools" (page 180).
- Preset a G30 position.
  For information, see "Use a G30 Position" (page 162).
- Read the currently programmed work offsets.
  For information, see "View Work Offsets" (page 154).

6.2.5 Conversational Tab

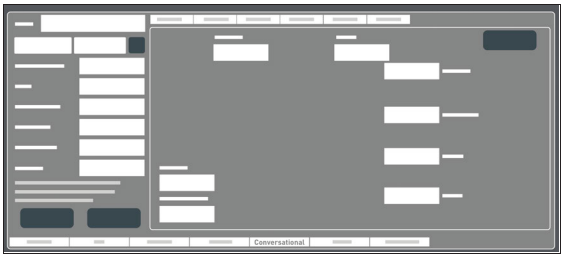

Figure 6-7: Conversational tab.

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 127).

6.2.6 Probe Tab

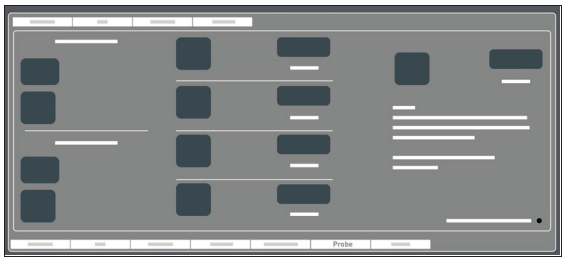

Figure 6-8: Probe tab.

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 149).

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" (page 229).
- Read error messages.
- Configure your internet connection.
  For information, see "Enable an Internet Connection" (page 138).
- Update or install a previous version of PathPilot.
  For information, see "Manage PathPilot Versions" (on the next page).

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 **116**
6.3.2 Position Status Area **117**
6.3.3 Manual Control Area **117**

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 155).
- Start, stop, or pause a G-code program.
  For information, see "Start a Program" (page 157); "Stop Machine Motion" (page 157); "Use the Feed Hold Function" (page 158).
- Turn coolant on or off.
  For information, see "Operate the Coolant Pump" (page 181).

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- Use overrides to change the feed rate, spindle speed, and maximum velocity.
  For information, see "Use the Feed Rate Override Function" (page 159); "Use the Maxvel Override Function" (page 160); "Use the Spindle Override Function" (page 161).
- Manually control a G-code program.
  For information, see "Use M01 Break Mode" (page 159); "Use Single Block Mode" (page 160).

6.3.2 Position Status Area

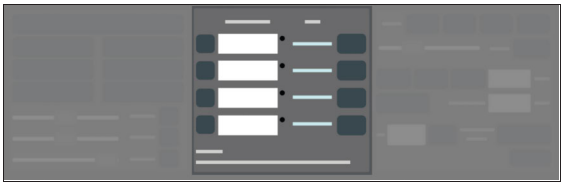


Figure 6-12: Position Status area.

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 174).
- 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 155); "View the Current Machine Position" (page 156); "View the Distance to Go" (page 158).
- Quickly determine which G-code modes are active.
  For information, see "View the Active G-Code Modes" (page 158).

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 174).
- Change the spindle speed or feed rate.
  For information, see "Change the Spindle Speed" (page 161); "Change the Feed Rate" (page 161).
- View or edit information about the current tool.
  For information, see "Change the Tool Number" (page 162); "Use a G30 Position" (page 162) "View the Tool Length" (page 163).

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" (on the next page)
- "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. Then, select **Update**.

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

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

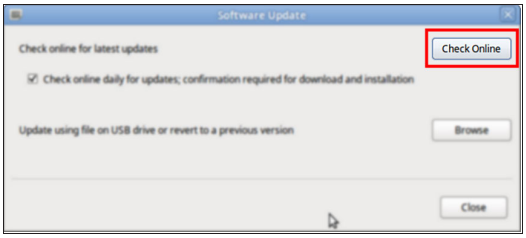


Figure 6-15: Software Update dialog box.

4. Select **Install**.

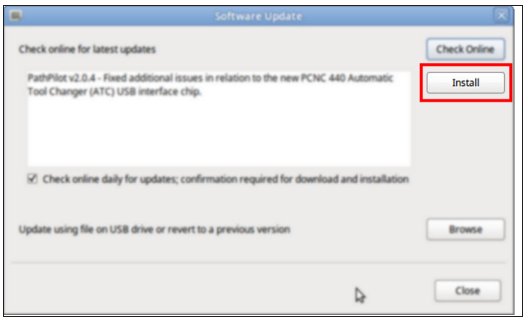


Figure 6-16: Install button on the Software Update dialog box.

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**.

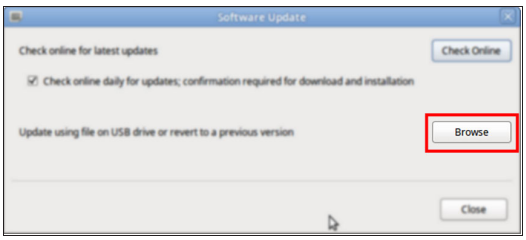


Figure 6-18: Software Update dialog box.

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.

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**.

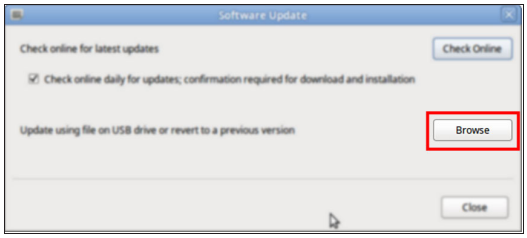


Figure 6-21: Software Update dialog box.

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

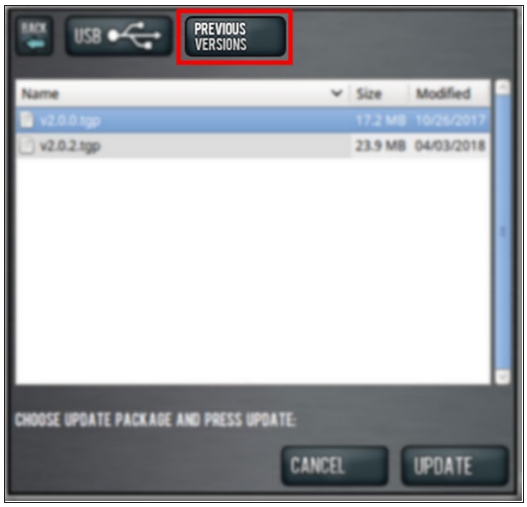


Figure 6-22: Browse dialog box.

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.

DRMACH

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 **122**
7.2 Machine Settings and Accessories **137**
7.3 Set Up G-Code Programs **149**
7.4 Run G-Code Programs **155**
7.5 Control G-Code Programs **158**
7.6 System File Management **168**

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 **122**
7.1.2 Edit G-Code **123**
7.1.3 Read G-Code **124**
7.1.4 Use Conversational Programming **127**

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" (below).

To load G-code:

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

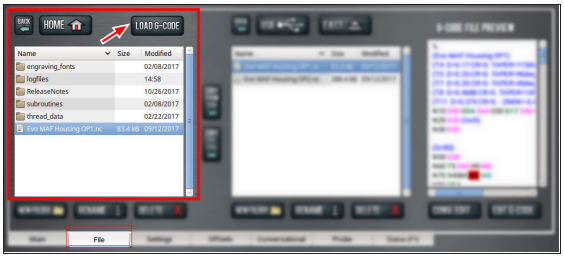


Figure 7-1: Controller Files window on the File tab.

> **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. For information, see "About System Files" (page 168).

To transfer files to and from the controller:

1. Insert a USB drive into any open USB port.
2. From the **File** tab, select the file to transfer (either in the **USB Files** window or the **Controller Files** window).

> **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 From USB** or **Copy to USB**.

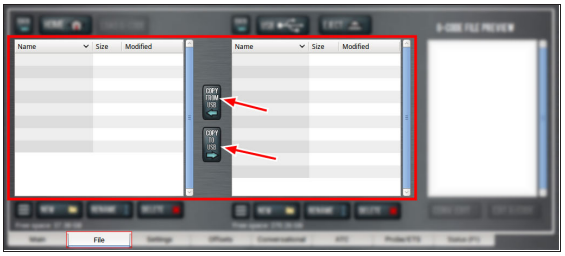


Figure 7-2: File tab.

> **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. Select **Eject**.
   It's safe to remove the USB drive from the controller.

About System Files

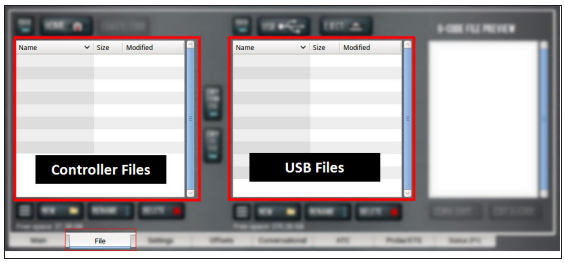


Figure 7-3: File tab.

PathPilot doesn't run G-code program files from a USB drive. You must first transfer files to the PathPilot controller. For information on transferring files, see "Transfer Files to and From the Controller" (above).

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.

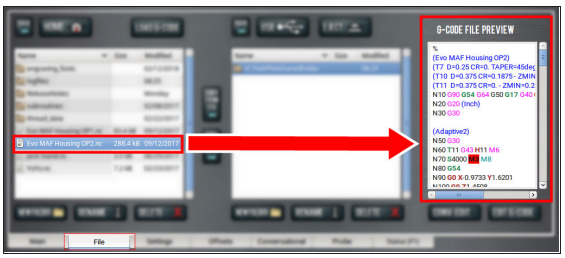


Figure 7-4: File tab.

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.

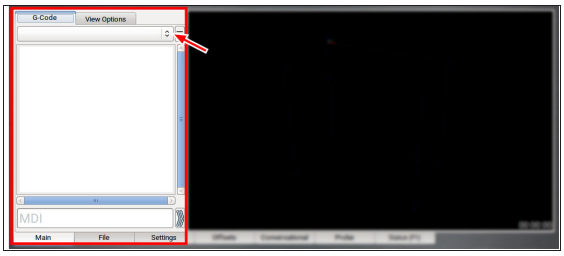


Figure 7-5: Recent Files menu on the Main tab.

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**.

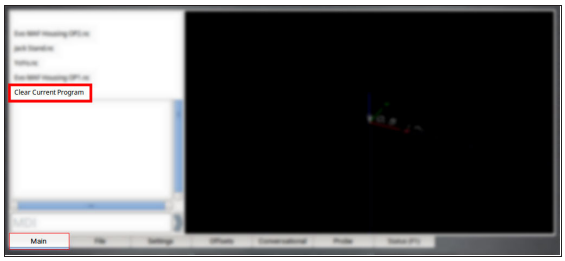


Figure 7-6: Recent Files menu on the Main tab.

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 **123**
Edit G-Code with Conversational Programming **123**

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" (on the previous page).

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" (on the previous page).

To edit G-code with conversational programming:

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.

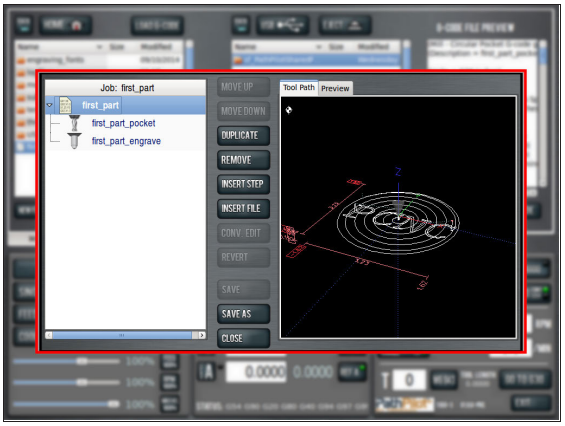


Figure 7-8: Job assignment editor.

3. Edit the file contents as needed. Do any of the following:

Change the Step Order 124
Create a New Job Assignment 124
Load an Existing G-Code File 124
Edit a Job Assignment 124

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 124
Search in the Code 124
Set a New Start Line 125
Change the View of the Tool Path Display 126

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**.

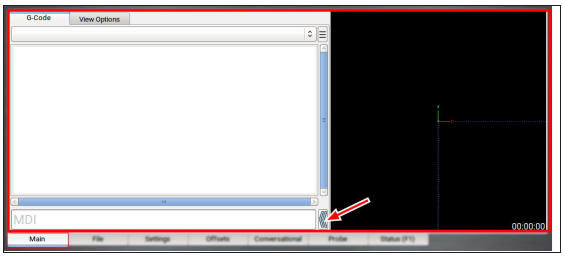


Figure 7-9: Window Expander on the Main tab.

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" (above).
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" (on the next page).
- **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.

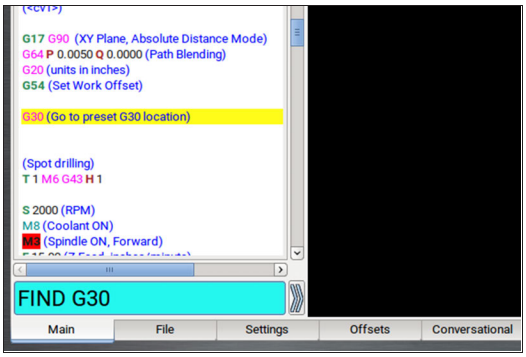


Figure 7-10: Search for a text command.

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

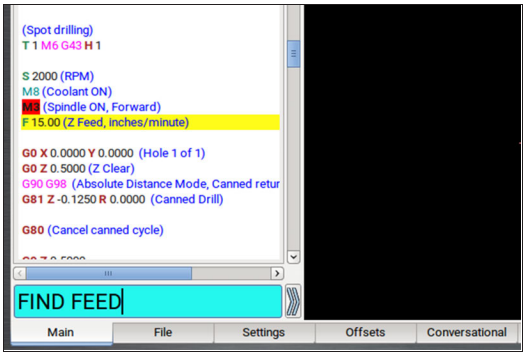


Figure 7-11: Search for a feed command.

   - `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:
   - Right-click any line in the program.

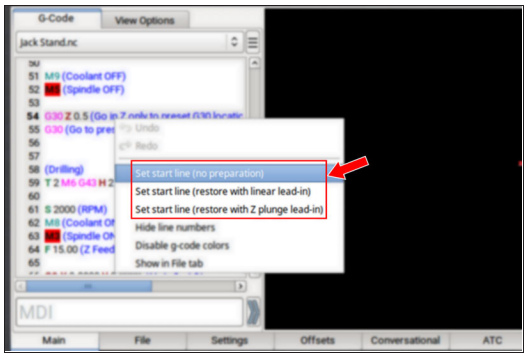


Figure 7-12: Accessing the Options menu by right-clicking.

   - 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 or fly cutter 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.

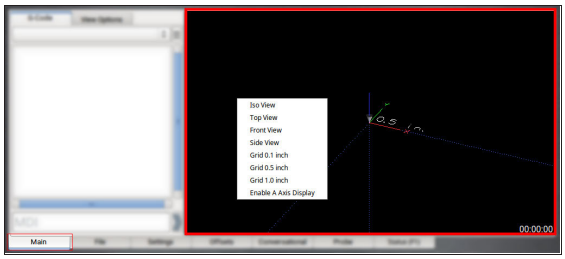


Figure 7-13: Tool Path display on the Main tab.

   - Select the **View Options** tab.

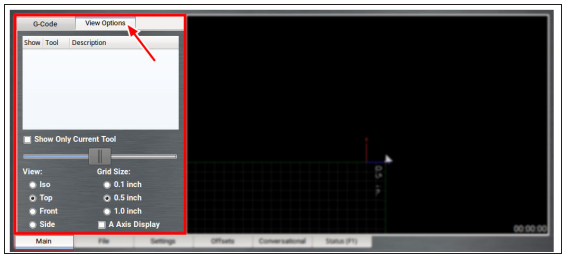


Figure 7-14: View Options tab on the Main tab.

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** 5 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 **127**
Create a Face on a Part **127**
Create a Profile on a Part **128**
Create a Pocket on a Part **130**
Create Hole Locations on a Part (Drill/Tap) **132**
Create Threads on a Part **134**
Create Text to Engrave on a Part **136**
Import a DXF File **136**

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.

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.

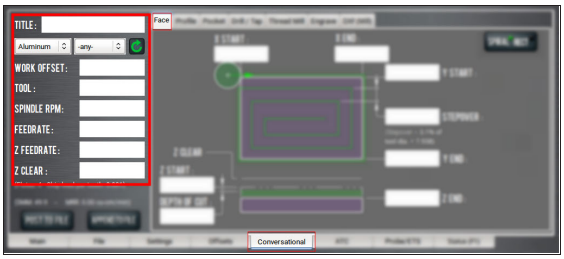


Figure 7-15: Conversational DROs on the Face tab.

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" (below).
   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).

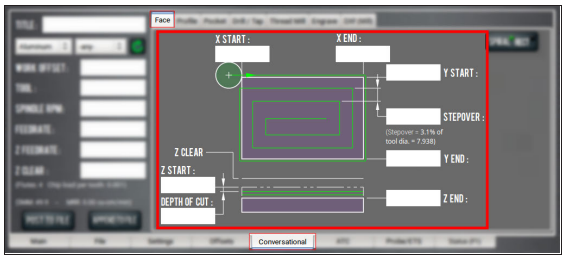


Figure 7-16: Program-specific DROs on the Face tab.

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" (on the previous page).

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" (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 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.

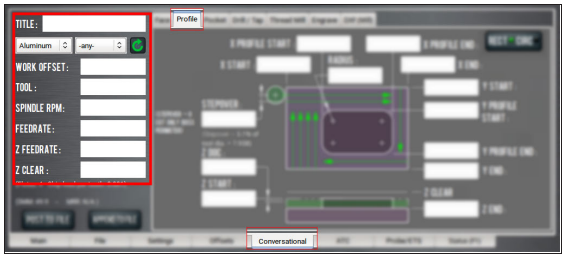


Figure 7-17: Conversational DROs on the Profile tab.

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).

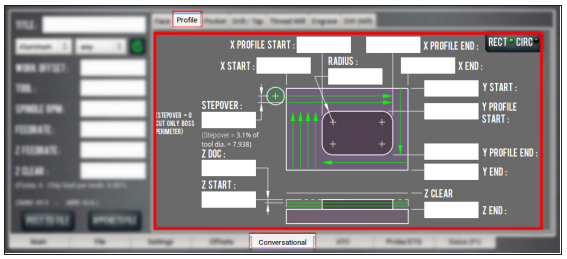


Figure 7-18: Program-specific DROs on the Profile tab.

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 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" (page 128).

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:

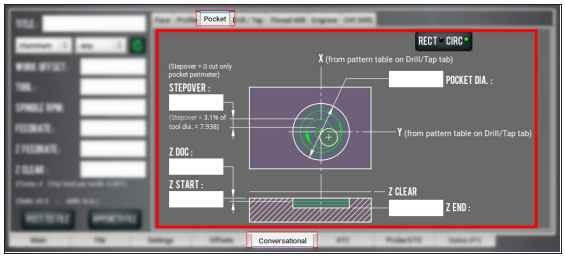
1. From the **Conversational** tab, select the **Pocket** tab.
2. From the **Conversational DROs** group, set the parameters for the pocket operation.

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.

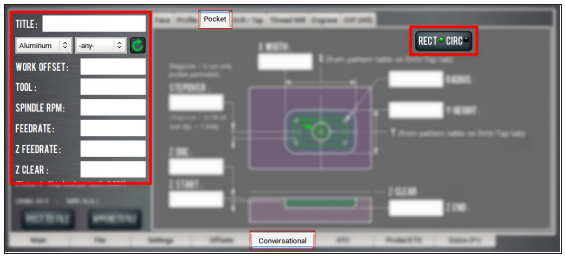
   c. In the **Stepover** DRO field, type the required distance between each rotation of the spiral cut. For a single cut around the inside perimeter of the pocket (to create a slot), type `0`.
   d. In the **Z Start** DRO field and the **Z End** DRO field, type the location of the first and last Z passes. 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.
   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).



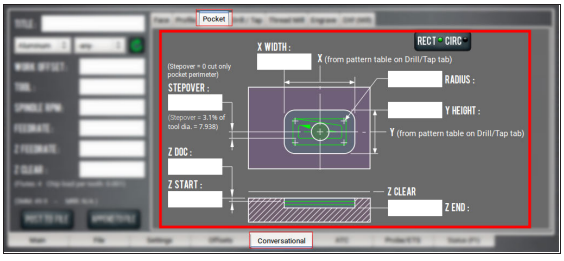
To create a rectangular pocket on a part:

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" (below)

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 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 know as a bolt pattern):

1. From the **Conversational** tab, select the **Drill/Tap** tab.

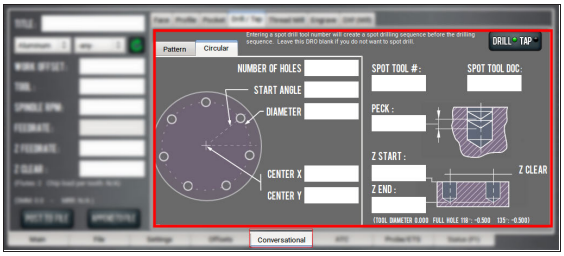


Figure 7-19: Drill/Tap tab on the Conversational tab.

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 134).

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.

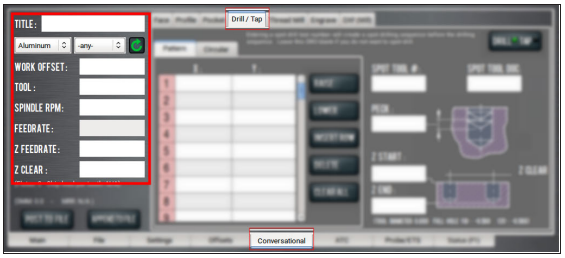


Figure 7-20: Drill/Tap tab on the Conversational tab.

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" (on the next page).
   - Go to "Create a Tapping Sequence" (page 134).

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.

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" (on the next page).

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" (on the next page).

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.

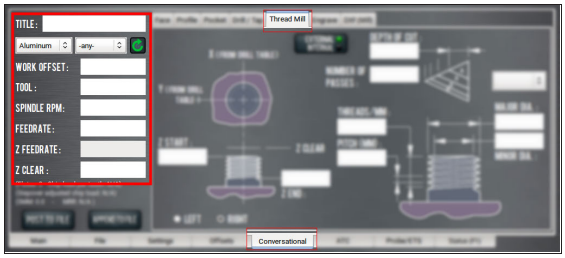


Figure 7-21: Conversational DROs on the Thread Mill tab.

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" (below).

> **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.

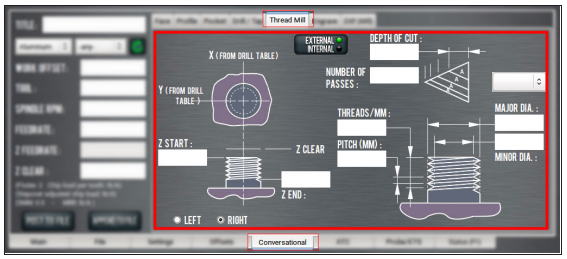


Figure 7-22: Program-specific DROs on the Thread Mill tab.

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" (on the previous page).

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" (below).

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.

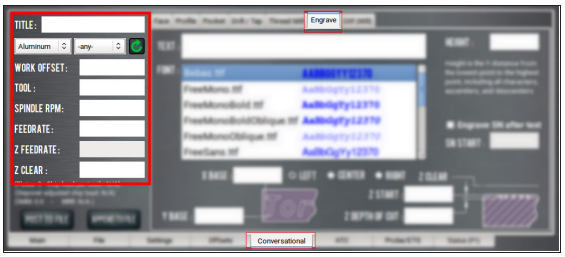


Figure 7-23: Conversational DROs on the Engrave tab.

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 122).

   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.

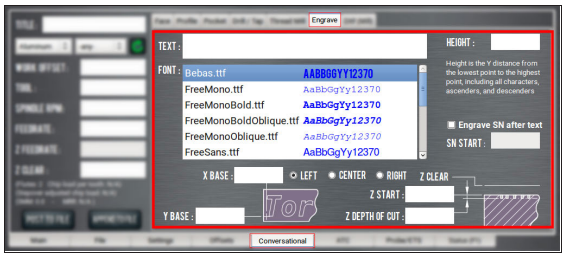


Figure 7-24: Program DROs on the Engrave tab.

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.

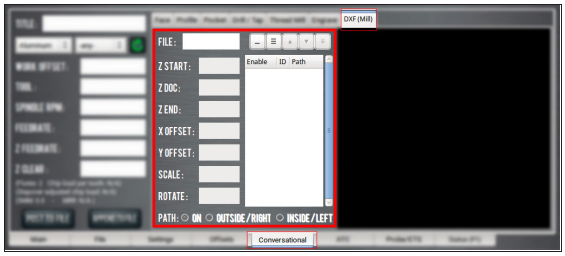


Figure 7-25: DXF tab on the Conversational tab.

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 122).

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.

> **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.

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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 Dropbox 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.

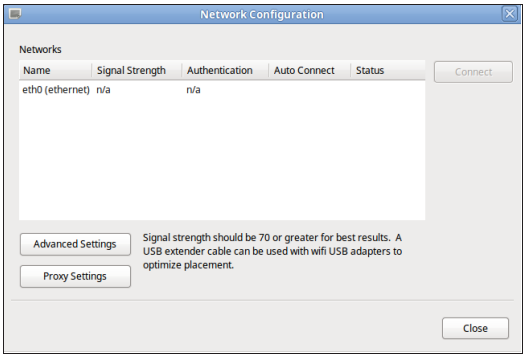


Figure 7-27: Network Configuration dialog box.

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.

3. Once connected, you can use the Dropbox and automatic updates features. Depending on what you want, see the following procedures:
   - "Connect to Dropbox" (below)
   - "Enable Automatic Updates" (on the next page)

Connect to Dropbox

> **Note:** Dropbox requires an internet connection. If you haven't yet enabled it, go to "Enable an Internet Connection" (above).

If desired, you can connect your PathPilot controller to a Dropbox account to easily synchronize your G-code files, which eliminates the need to transfer them with a USB drive.

> **Note:** Dropbox stops synchronizing once the PathPilot controller's internal drive has less than 500 MB of free space. To avoid this, we recommend that you organize your Dropbox account on a separate computer before you connect to Dropbox with PathPilot. Only store files in the top-level that you want synchronized to your PathPilot controller.

To connect to Dropbox:

1. From the PathPilot interface, on the **Main** tab, in the **MDI Line** DRO field, type `ADMIN DROPBOX`.

2. Select the **Enter** key.
   The **Dropbox Configuration** application displays.

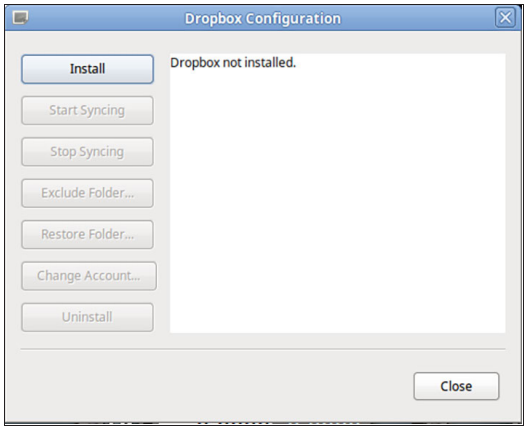


Figure 7-28: Dropbox Configuration application.

3. Select **Install**.
   The **Dropbox Installation** dialog box displays.
4. Select **OK**.

Figure 7-29: Dropbox Installation dialog box.

   The Dropbox installation starts and continues for about a minute. When done, a web browser displays.

5. From the web browser, sign in or create a Dropbox account.
   The PathPilot controller connects to the Dropbox account, creates a local **Dropbox** folder that is visible in **File** tab, and synchronizes the folder.
6. Because Dropbox stops synchronizing once the PathPilot controller's internal drive has less than 500 MB of free space, we recommend that you exclude large or unrelated folders from synchronization. Select **Exclude Folder...**.

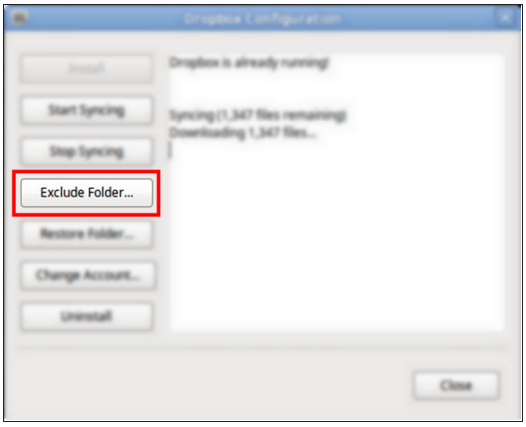


Figure 7-30: Exclude Folder button.

   The **Add Folder to Excluded Set** dialog box displays.
7. In the **Add Folder to Excluded Set** dialog box, type the name of the folder to exclude.

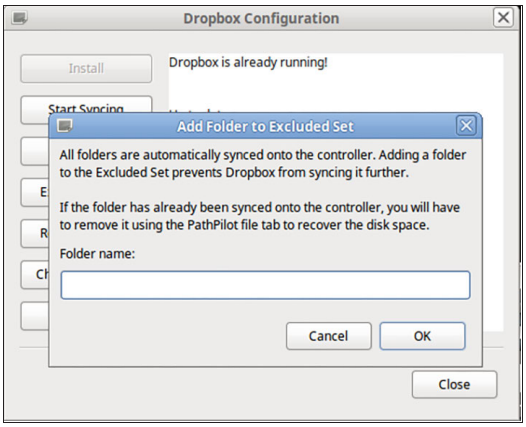


Figure 7-31: Add Folder to Excluded Set dialog box.

> **Note:** You can only exclude folders, not individual files.

8. Select **OK**.
9. Select **Close**.
   The PathPilot controller is now connected to Dropbox.

Enable Automatic Updates

> **Note:** Automatic updates require an internet connection. If you haven't yet enabled it, go to "Enable an Internet Connection" (on the previous page).

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.

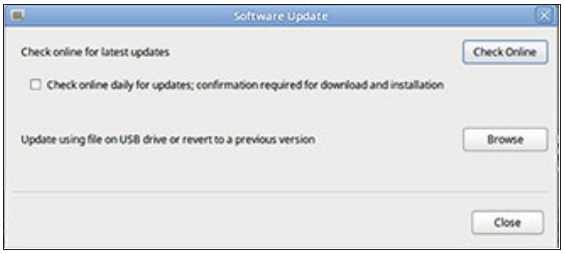


Figure 7-32: Software Update dialog box.

2. From the **Software Update** dialog box, select the **Check online daily for updates; confirmation required for download and installation** checkbox.
3. 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:

1. From the **Network Name** field, type a new network name.

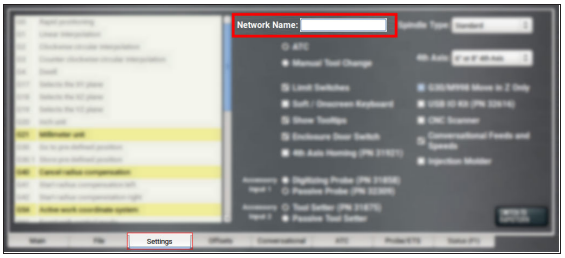


Figure 7-33: Network Name field on the Settings tab.

> **Note:** The network name must be unique within your network.

2. Select the **Enter** key.
3. 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.

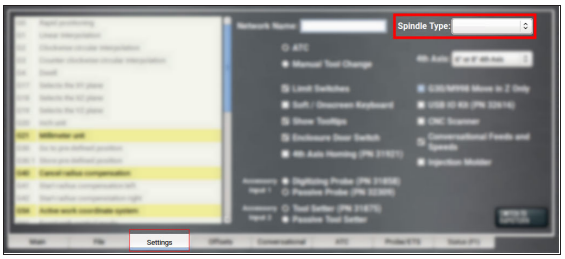


Figure 7-34: Spindle Type field on the Settings tab.

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:

1. From the PathPilot interface, on the **Settings** tab, select **Portrait** from the **Layout** drop-down menu. Restart the controller.

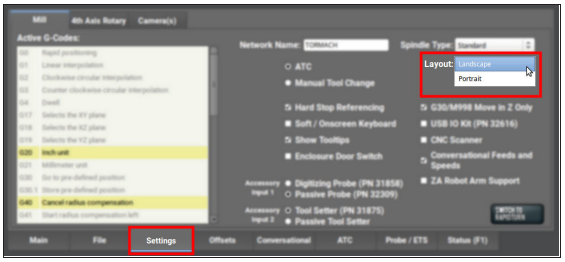


Figure 7-35: Layout drop-down menu on the Settings tab.

2. Rotate the monitor to the portrait orientation. You can rotate it either left or right, depending on what's easier for your setup.

3. 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.

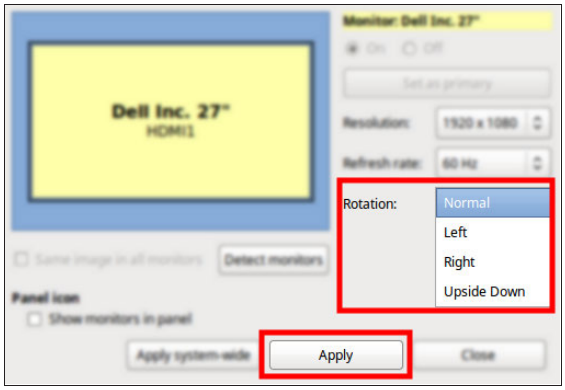


Figure 7-36: Monitor configuration dialog box.

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.

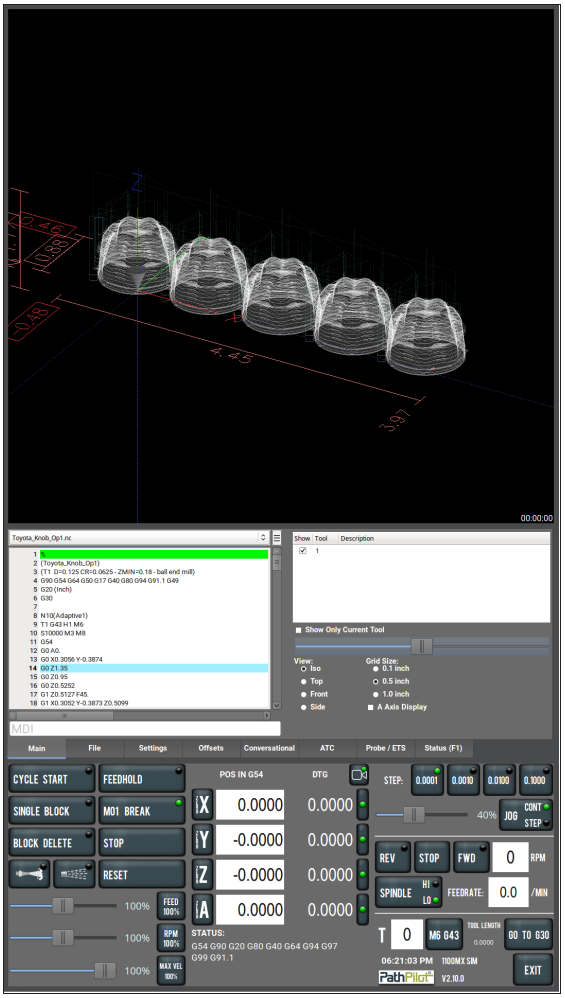


Figure 7-37: Tool Path window in portrait screen layout.

- 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.

- When browsing G-code files using the File tab, file previews display on the top portion of the screen.

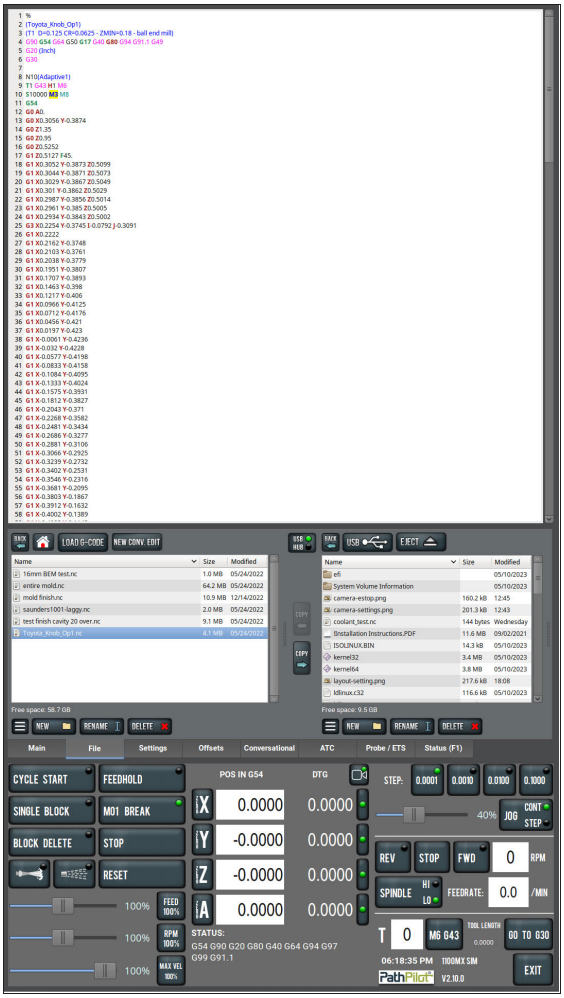


Figure 7-38: File tab G-code preview in portrait screen layout.

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.

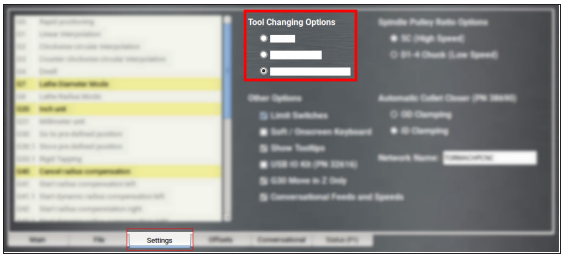


Figure 7-39: Tool change method options on the Settings tab.

About Automatic Tool Changes

If you're using an Automatic Tool Changer (ATC) to make tool changes, PathPilot does the following:

1. Looks for an ATC.
   In the PathPilot interface, the ATC tab displays.
2. 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:

1. The Cycle Start button flashes.
2. The Tool Path display shows the requested tool number.

7.2.6 Disable Limit Switches

To provide a temporary workaround for a malfunctioning limit switch circuit, you can disable the limit switches. For information, see About Limit Switches.

> **Note:** By default, the Limit Switches checkbox is selected.

To disable limit switches:

1. From the **Settings** tab, clear the **Limit Switches** checkbox.

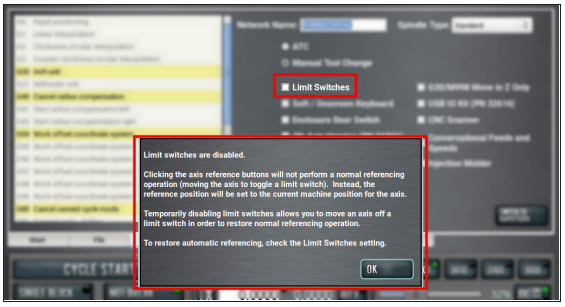


Figure 7-40: Limit Switches checkbox on the Status tab.

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.

7.2.7 Limit G30 Moves

You can limit G30 moves so that only the Z-axis moves. For information, see "About G30" (page 163).
To limit G30 moves:

From the **Settings** tab, select **G30/M998 Move in Z Only**.

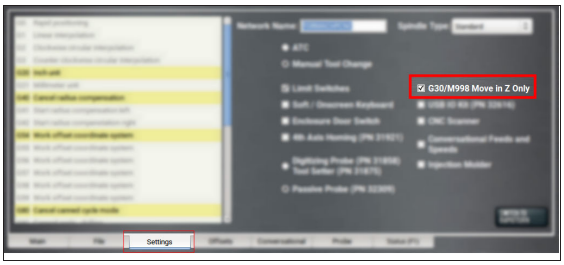


Figure 7-41: Settings tab.

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 162).
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**.

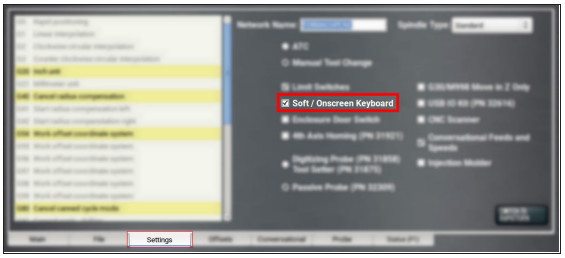
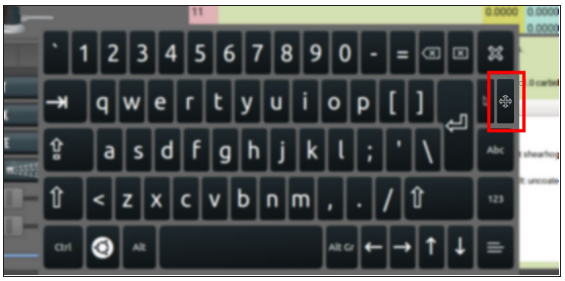
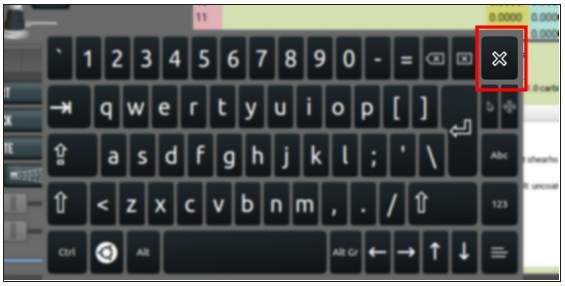


Figure 7-42: Settings tab.

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.

Figure 7-43: 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)**.

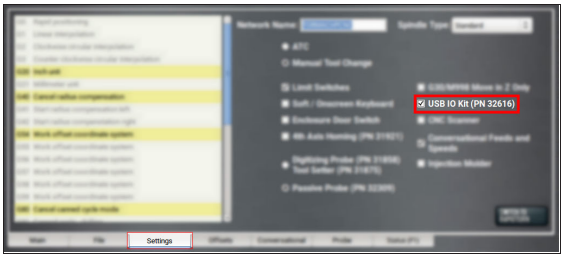


Figure 7-44: Settings tab.

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**.

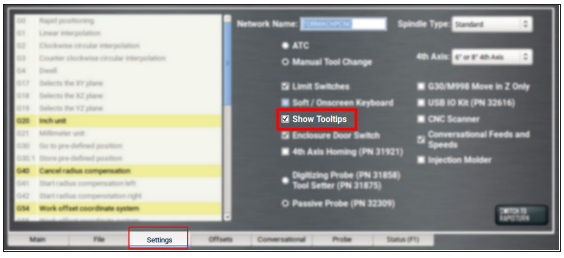


Figure 7-45: Show Tooltips checkbox.

> **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**.

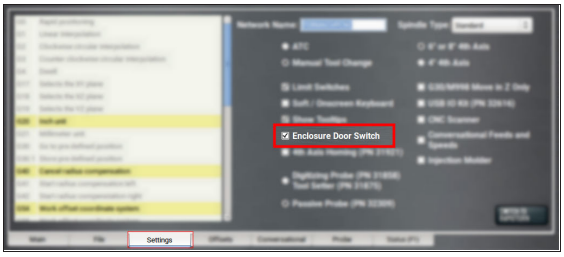


Figure 7-46: Settings tab.

On the **Status** tab, the **Door Locked / Open** LEDs display.

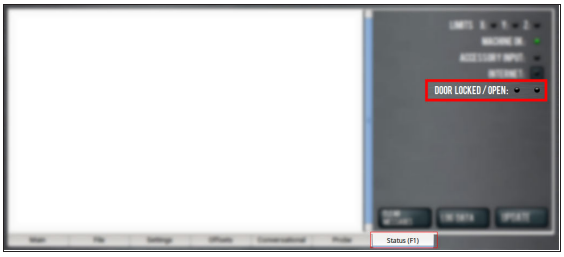


Figure 7-47: Status tab.

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.

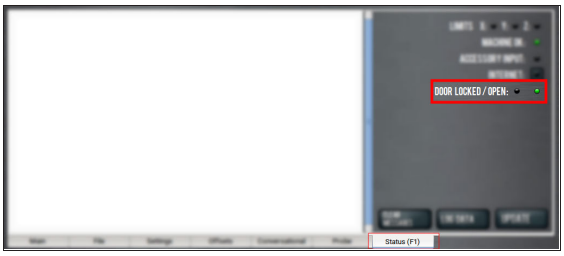


Figure 7-48: Door Open LED on the Status tab.

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 164).

- From the **Settings** tab, select **Conversational Feeds and Speeds**.

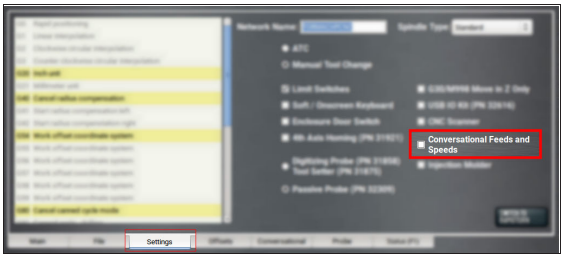


Figure 7-49: Settings tab.

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**.

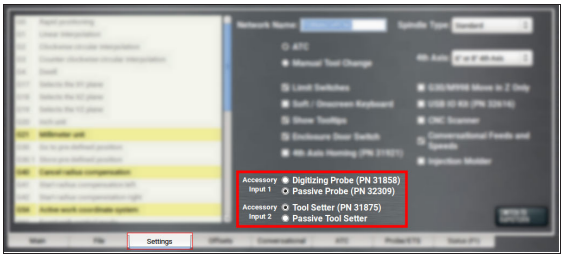


Figure 7-50: Settings tab.

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**.

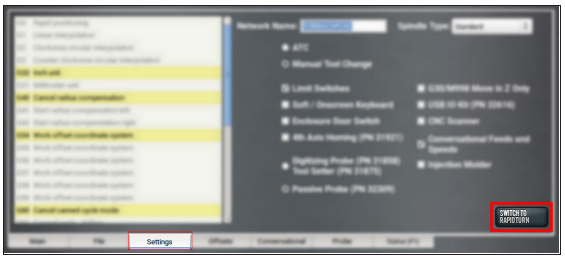


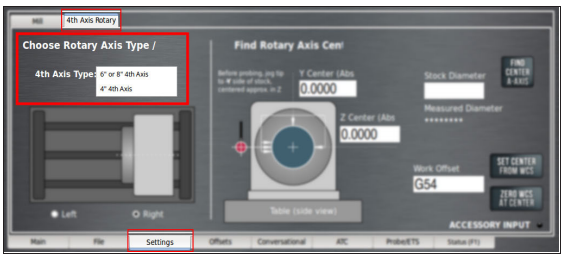
Figure 7-51: Switch to RapidTurn button on the Settings tab.

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)**.

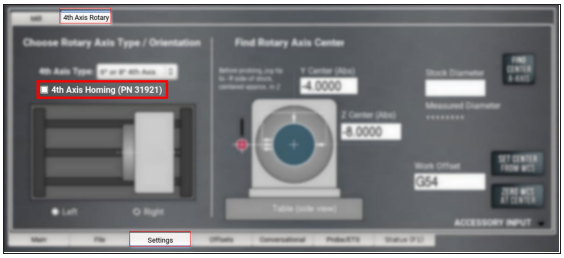


Figure 7-52: Settings tab.

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.

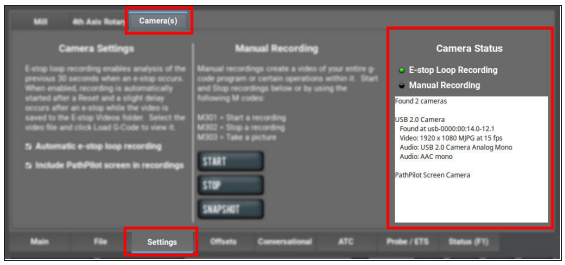


Figure 7-53: USB camera status.

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 7-54: Manual recording controls.

- Select the **Video Camera Recording** button in the **Persistent Controls** section.

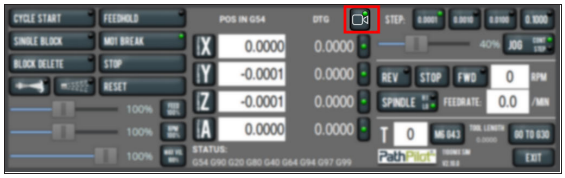


Figure 7-55: Video Camera Recording button.

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 7-56: 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.

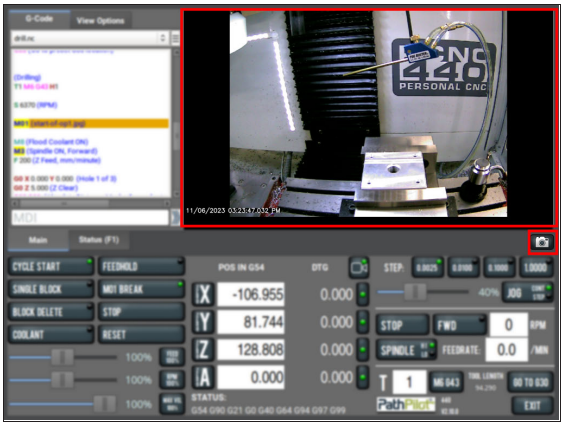


Figure 7-57: Example of taking a photo.

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.

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:

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 "Display Information and Capture Images During an M00 or M01 Break" (page 213).

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 **149**
7.3.2 Set Tool Length Offsets **151**
7.3.3 Set Work Offsets **154**
7.3.4 View Work Offsets **154**
7.3.5 View Available G-Code Modes **155**

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 145).

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-**.

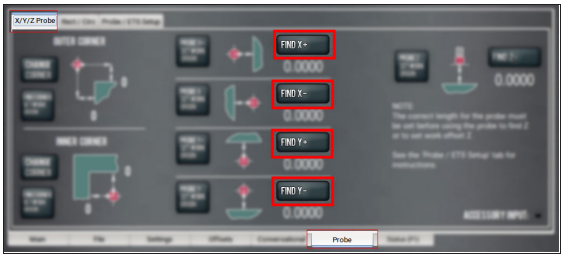


Figure 7-58: Probe tab.

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**.

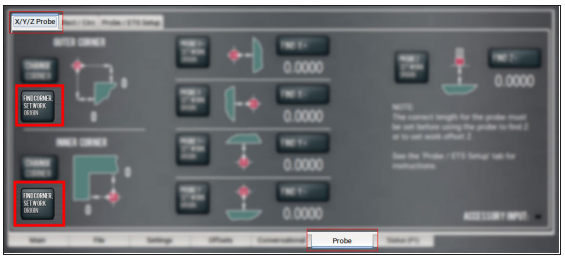


Figure 7-59: Probe tab.

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.

3. 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**.

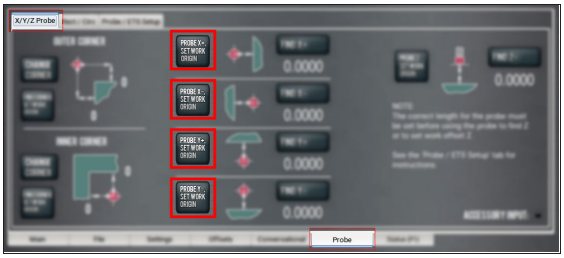


Figure 7-60: Probe tab.

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

1. From the PathPilot interface, on the **Probe** tab, select the **Rect/Circ** tab.
2. Position the probe near the center of the pocket.
3. Select **Find Center, Set Work Origin** as shown in the following image.

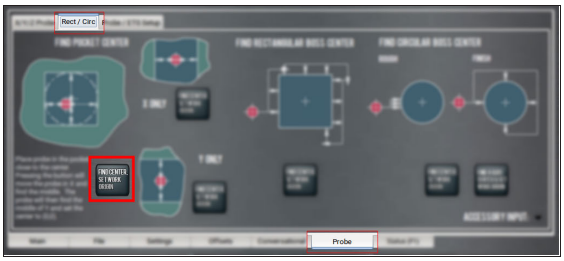


Figure 7-61: Probe tab.

Find the Center of a Slot

1. From the PathPilot interface, on the **Probe** tab, select the **Rect/Circ** tab.
2. Position the probe near the center of the slot.
3. 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.

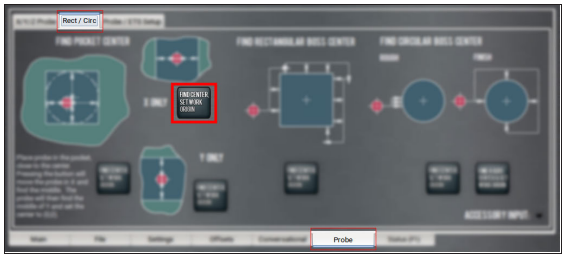


Figure 7-62: Probe tab.

   - To probe the slot in the **Y** direction only, select **Find Center, Set Work Origin** as shown in the following image.

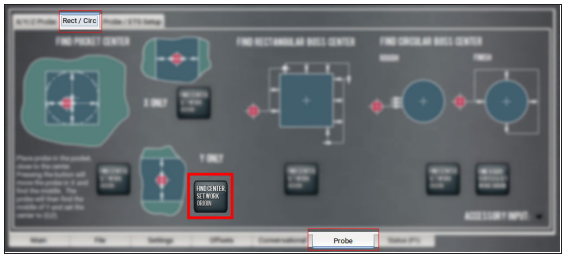


Figure 7-63: Probe tab.

Find the Center of a Rectangular Boss

1. From the PathPilot interface, on the **Probe** tab, select the **Rect/Circ** tab.
2. 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.

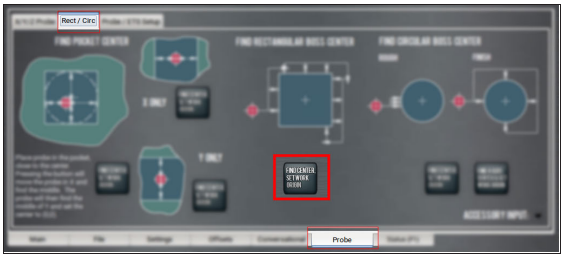


Figure 7-64: Probe tab.

The probe moves around the edge of the workpiece to find the center.

Find the Center of a Circular Boss

1. From the PathPilot interface, on the **Probe** tab, select the **Rect/Circ** tab.
2. 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.

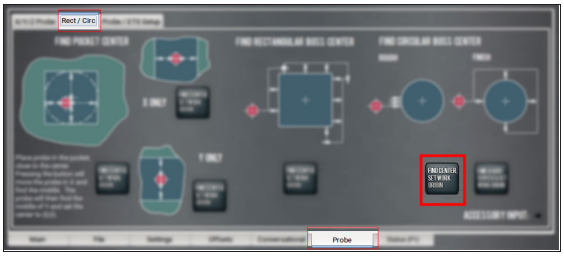


Figure 7-65: Probe tab.

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**.

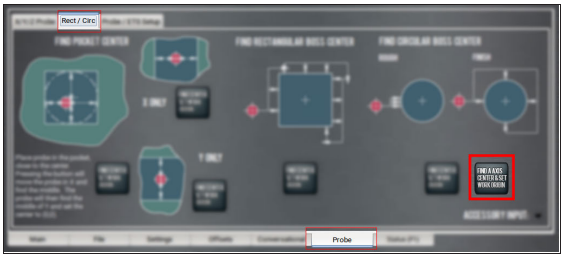


Figure 7-66: Probe tab.

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 178).

> **Note:** You can import a .csv file with tool length offset data. For information, see "Import and Export the Tool Table" (page 170).

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 184).
3. From the PathPilot interface, on the **Offsets** tab, verify that the **Tool** tab is selected.
4. Find the **Tool Table** window.

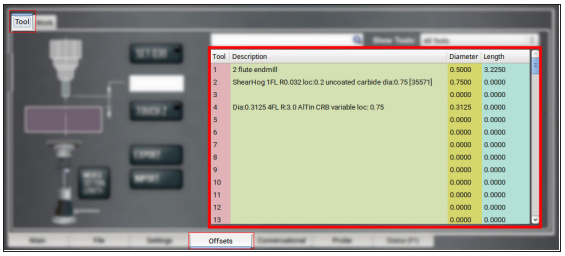


Figure 7-67: Tool Table window on the Offsets tab.

5. Depending on your workflow, you can measure your tools using any of the following methods:
   - **Use a Height Gauge** For information, see "Use a Height Gauge to Measure Tools" (page 180).
   - **Use an Electronic Tool Setter** For information, see "Use an Electronic Tool Setter (ETS) to Measure Tools" (page 180).
   - **Touch Off of a Known Reference Height** For information, see "Touch Off the Tool Length Offsets" (page 178).

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. To make sure tool length offsets are consistent among your tools, we recommend you use Tormach Tooling System (TTS) tool holders. Set the tool length offset after placing a tool in the Tormach Tooling System (TTS) tool holder — each tool and its tool holder only need to be measured once.

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.

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 **152**
Measure Tools Using a Known Reference Height **152**

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 175).

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 7-68: 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" (page 187).

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.

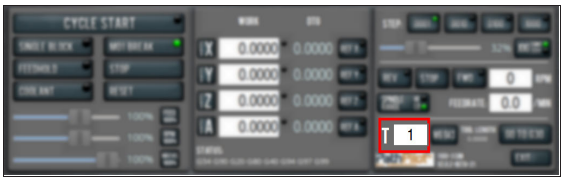


Figure 7-69: Tool DRO field.

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.

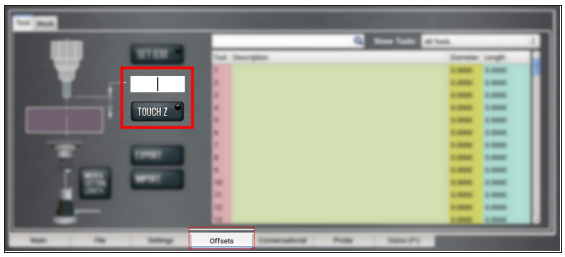


Figure 7-70: Touch Z DRO field and button.

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 Electronic Tool Setter (PN 31875) is a device used to measure the length of a cutting tool.
To use an ETS to measure tools:

1. Plug in the ETS to the **Accessory 2** port.
2. Put the ETS on the known reference surface below the spindle.
3. From the PathPilot interface, on the **Offsets** tab, in the **Tool Table** window, in the **Description** column, type a description for the tool.
4. In the **Diameter** column, type the diameter of the tool. Then select the **Enter** key.
5. Put a tool holder into the spindle.
6. From the PathPilot interface, type the tool number in the **Tool** DRO field. Then select the **Enter** key.

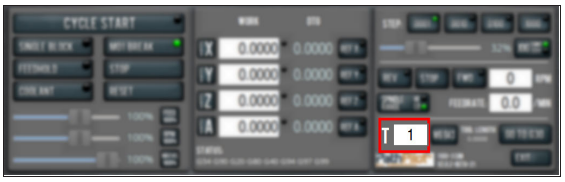


Figure 7-71: Tool DRO field.

7. Jog the Z-axis down (-Z) until it is above the ETS.
8. From the **Offsets** tab, on the **Tool** tab, select **Move and Set Tool Length**.

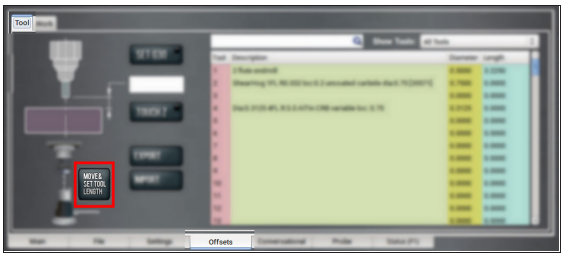


Figure 7-72: Tool tab on the Offsets tab.

> **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).

9. From the **Tool Table** window, in the **Length** column, verify that the length of the tool is correct.

Use a Height Gauge to Measure Tools

1. Before measuring a tool, you must first zero the height gauge using a precision surface, like a Granite Surface Plate (PN 31713): Move the height gauge to the top of the Granite Surface Plate.
2. Press the **Zero** button on the touch trigger.
   The height gauge is zeroed.
3. Insert a tool holder into the Granite Surface Plate.
4. From the PathPilot interface, on the **Offsets** tab, select the **Tool** tab.
5. In the **Tool Table** window, type a description for the tool.
6. Move the height gauge on the Tormach Tool Assistant Set to the end of the tool's cutting edge.

7. Write down the measured tool length, and then type that value into the **Length** column on the **Tool Table** window. Then select the **Enter** key.

7.3.3 Set Work Offsets

To set the current axis location to zero in the active work coordinate system:

- Select **Zero [Axis]**.

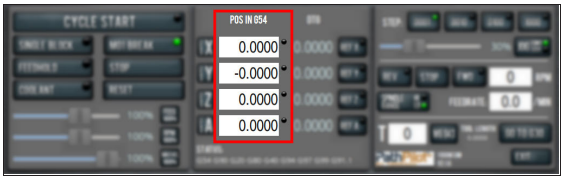


Figure 7-73: Work Offset DRO fields.

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.

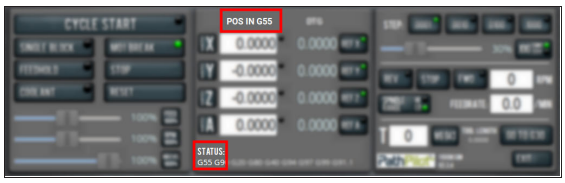


Figure 7-74: Work offset indicated in the PathPilot interface.

> **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 186).

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
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.

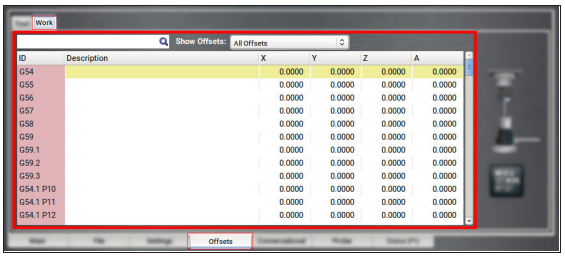


Figure 7-75: Work Offsets Table window.

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.

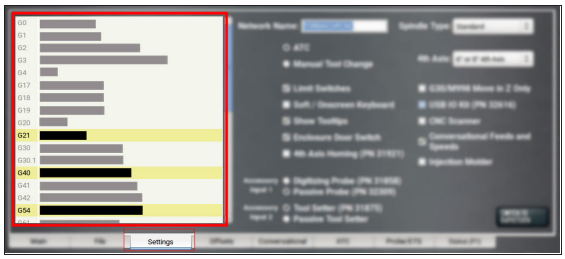


Figure 7-76: G-code Description window on the Settings tab.

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 155
7.4.2 View the Active Axis to Jog 155
7.4.3 Jog the Machine 155
7.4.4 View the Current Machine Position 156
7.4.5 Reference the Machine 156
7.4.6 Start a Program 157
7.4.7 Stop Machine Motion 157
7.4.8 Operate the Coolant Pump 157
7.4.9 View the Active G-Code Modes 158
7.4.10 View the Distance to Go 158

7.4.1 Bring the Machine Out of Reset

- Select **Reset**.

Figure 7-77: Reset button.

For more information on reset mode, see "About Reset Mode" (below).

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 7-78: Work Offset DRO fields.

For information, see "Jog the Machine" (page 174).

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.

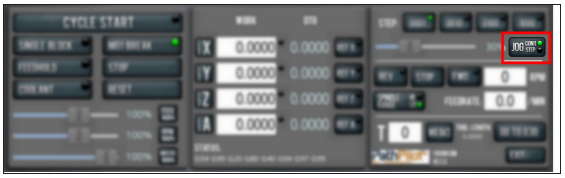


Figure 7-79: Jog button.

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 7-80: Jog Speed slider.

For more information on continuous velocity mode, see "About Continuous Velocity Jogging" (page 175).

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.

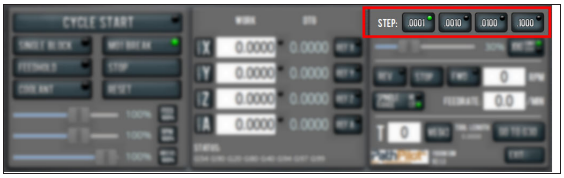


Figure 7-81: Step buttons (in G20 mode).

- 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 175).

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**.

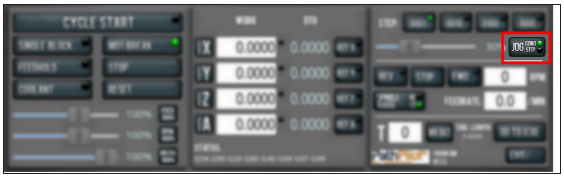


Figure 7-82: Continuous velocity jogging controls.

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 7-83: Jog Speed slider.

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.

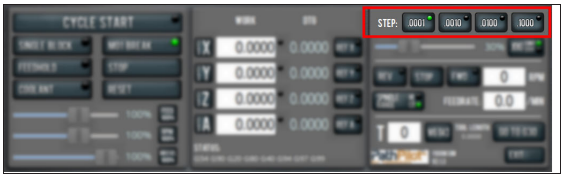


Figure 7-84: Step buttons (in G20 mode).

7.4.4 View the Current Machine Position

➢ Identify the **Work Offset** DRO fields.

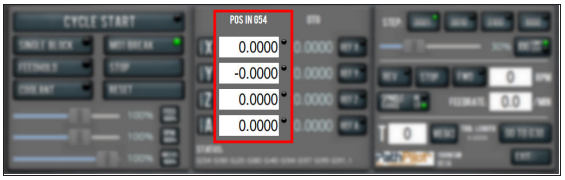


Figure 7-85: Work Offset DRO fields.

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).

7.4.5 Reference the Machine

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 7-86: 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" (page 185).

About Referencing

You must reference the machine to establish a known position for PathPilot. The position that's set while referencing the machine is the origin of the machine coordinate system. Without referencing the machine, PathPilot won't know the current position of the machine axes.

You must reference the machine at the following times:

- After you power on the machine
- After you push in the Emergency Stop button
- Before running a G-code program
- Before using MDI commands
- Before setting work or tool offsets
- After a collision or an axis stall/fault

When referencing, the machine moves each axis to the end of its travel. The machine stops at the limit switch, which sets the axis' reference position.

7.4.6 Start a Program

➢ From the PathPilot interface, in the **Main** tab, select **Cycle Start**.

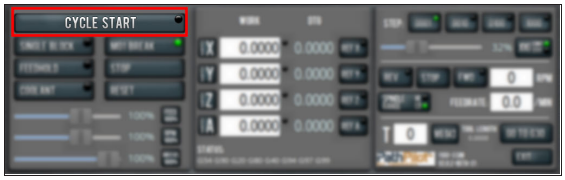


Figure 7-87: Cycle Start button.

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 114).
- Before you've loaded a G-code program. For information, see "Load G-Code" (page 177).
- Before referencing the machine. For information, see "Reference the Machine" (page 174).

7.4.7 Stop Machine Motion

➢ From the **Program Control** area, select **Stop**.

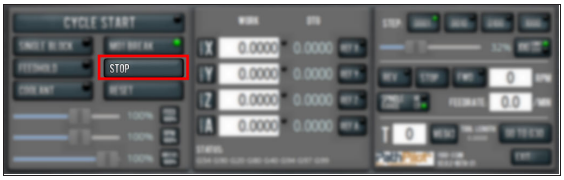


Figure 7-88: Stop button.

7.4.8 Operate the Coolant Pump

To turn coolant on or off:

➢ Select **Coolant**.

Figure 7-89: 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.

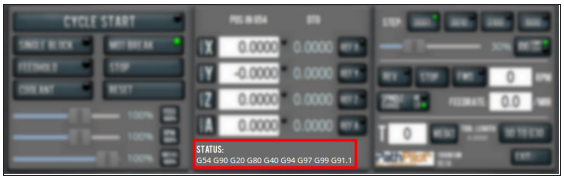


Figure 7-90: Status read-only DRO field.

For more information on G-code modes, go to "View Available G-Code Modes" (page 155).

7.4.10 View the Distance to Go

To view the distance to go:

- Identify the **DTG** read-only DRO fields.

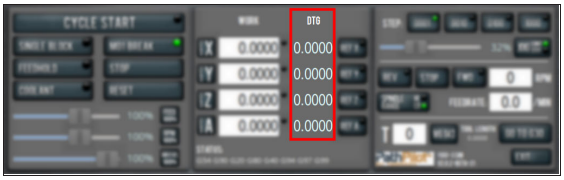


Figure 7-91: DTG read-only DRO fields.

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.

7.5 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 158
7.5.2 Use the Feed Rate Override Function 159
7.5.3 Use M01 Break Mode 159
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7.5.5 Use Single Block Mode 160
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7.5.7 Change the Feed Rate 161
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7.5.13 Copy Recently Entered Commands 164
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7.5.15 Use Cycle Counters (M30 and M99) 167

7.5.1 Use the Feed Hold Function

- Select **Feed Hold**.

Figure 7-92: 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" (on the previous page).

> **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.

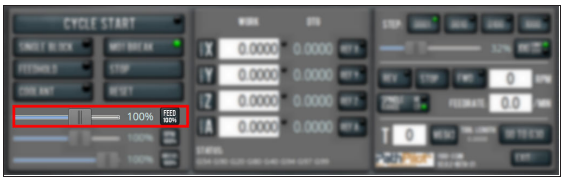

Figure 7-93: Feed Rate Override slider.

> **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 overriden).

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 7-94: 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 157).
- **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 146).

7.5.4 Use the Maxvel Override Function

To use the maxvel override function:

- Using the **Maxvel Override** slider, change the maximum velocity by a specified percentage.

Figure 7-95: 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 7-96: 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 157).
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" (on the previous page).

> **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 specific percentage.

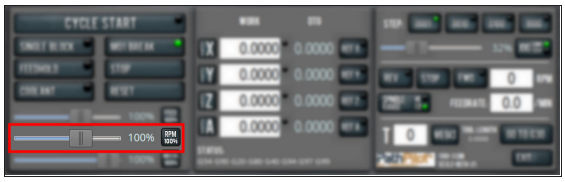

Figure 7-97: Spindle Override slider.

> **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 overriden).

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.

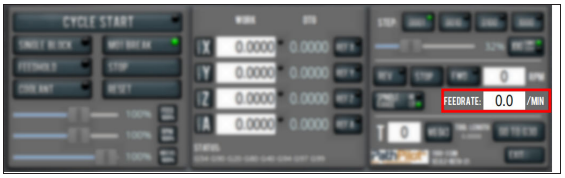

Figure 7-98: Feed Rate DRO field.

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.

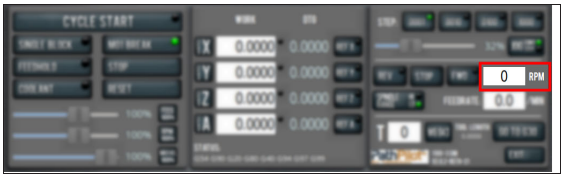

Figure 7-99: Spindle RPM DRO field.

> **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" (page 176).

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 "Change the Spindle Speed Range" (page 176).

Spindle Controls Reference

The spindle speed is measured in revolutions per minute (RPM).
Two speed ranges are available:

- **Low** 175 rpm to 3250 rpm
- **High** 525 rpm to 10,000 rpm

Use the low speed range when you're using larger cutting tools, or machining materials with lower surface speeds (like steel or stainless steel).
Use the high speed range when you're using smaller cutting tools, or machining materials with higher surface speeds (like aluminum, brass, or plastic).
To move your spindle speed range from one to the other, see "Change the Spindle Speed Range" (page 176).

7.5.9 Change the Tool Number

The Tool DRO field shows the tool currently in the spindle.

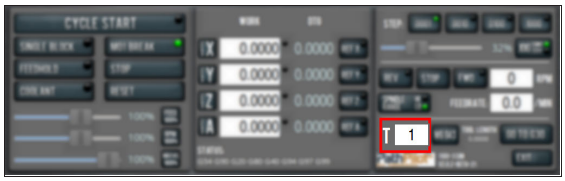

Figure 7-100: Tool DRO field.

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.
- 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 178). 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" (on the next page).
To set a G30 position:

1. Jog the machine to the desired G30 position.
2. From the **Offsets** tab, select **Set G30**.

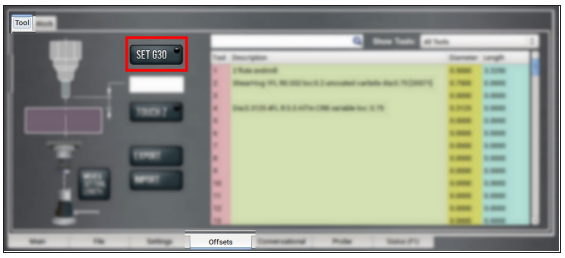

Figure 7-101: Set G30 button.

To go to a set G30 position:

- Do one of the following:
  - Use a `G30` command in a G-code program.
  - Select **Go To G30**.

Figure 7-102: 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" (on the previous page).
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 143).

> **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.

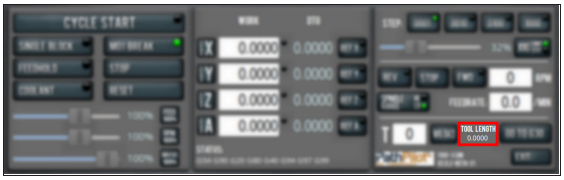

Figure 7-103: Tool Length DRO field.

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.

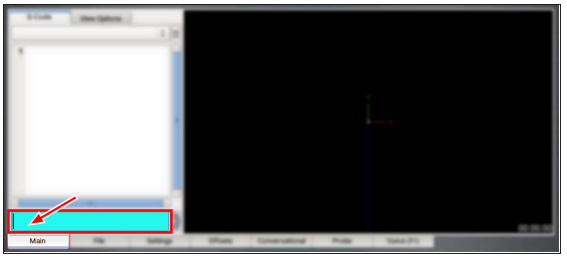

Figure 7-104: MDI Line DRO field.

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 CALC`	Open the calculator.
`ADMIN CONFIG`	Change the configuration of the PathPilot interface.
`ADMIN DATE`	Customize the PathPilot controller's date and time.
`ADMIN DISPLAY`	Customize the PathPilot controller's screen display.
`ADMIN DROPBOX`	Connect your controller to a Dropbox account.

Admin Command	Use to...
ADMIN KEYBOARD	Customize the PathPilot controller's keyboard layout.
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 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 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	Configure the optional Touch Screen Kit.

7.5.13 Copy Recently Entered Commands

1. From the **MDI Line** DRO field, press either the **Up Arrow** key or the **Down Arrow** key.
   The previously entered command displays.
2. 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).

7.5.14 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**.

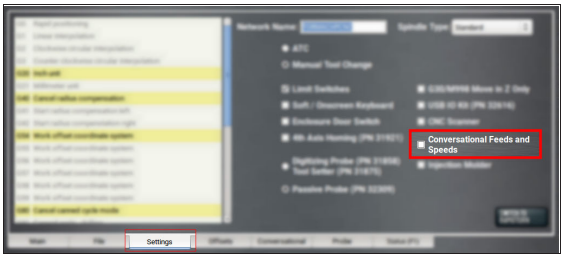

Figure 7-105: Settings tab.

2. From the **Conversational** tab, locate the **Material** dropdowns in the **Conversational** DROs group.

Figure 7-106: 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**
   - **Stepover**
   - **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.

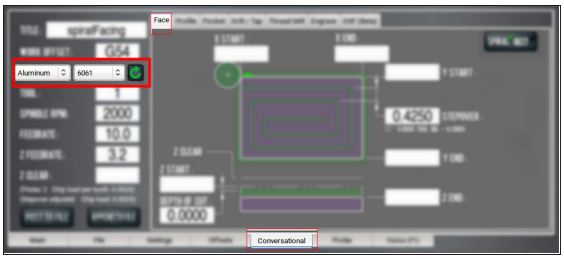

Figure 7-107: Refresh button on the Conversational tab.

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" (below).

To manually enter tool descriptions:

1. From the PathPilot interface, on the **Offsets** tab, identify the **Tool Table** window.
2. Select a blank line.
3. 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.

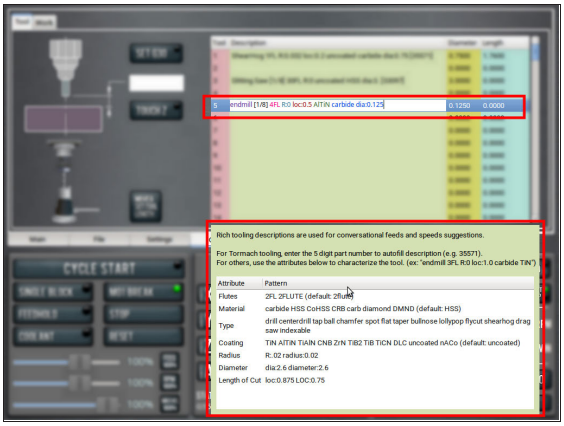

Figure 7-108: A manually-entered tool description.

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:03 AlTiN 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 nitrade 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

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.

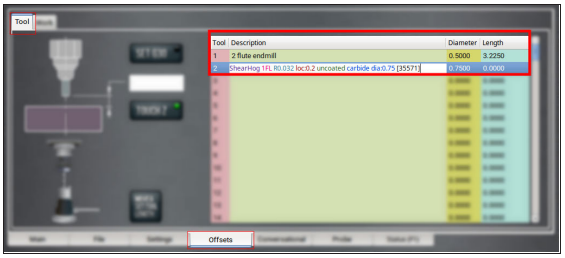

Figure 7-109: An automatically-generated tool description for a Tormach tool.

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.
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).
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
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.

7.6 SYSTEM FILE MANAGEMENT

To keep the files on your system backed up and organized, use the following controls:

7.6.1 Manage System Files 168
7.6.2 Create Backup Files 168
7.6.3 Restore Backup Files 169
7.6.4 Import and Export the Tool Table 170

7.6.1 Manage System Files

Use the File tab to manage system files on the PathPilot controller. For information, see "About System Files" (below).
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**.

About System Files

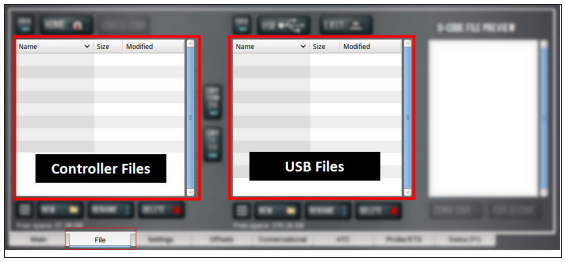

Figure 7-110: File tab.

PathPilot doesn't run G-code program files from a USB drive. You must first transfer files to the PathPilot controller. For information on transferring files, see "Transfer Files to and From the Controller" (page 122).

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.

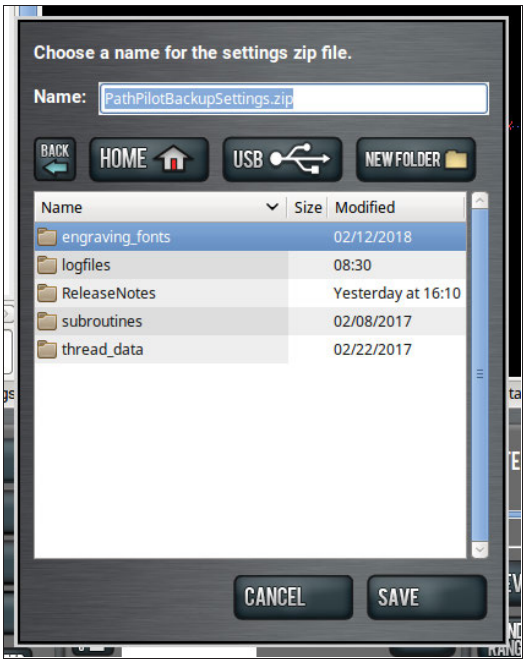

Figure 7-111: Admin Settings Backup dialog box.

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.

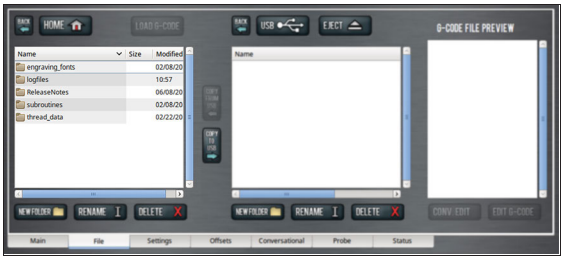

Figure 7-112: Controller Files window on the File tab.

> **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.

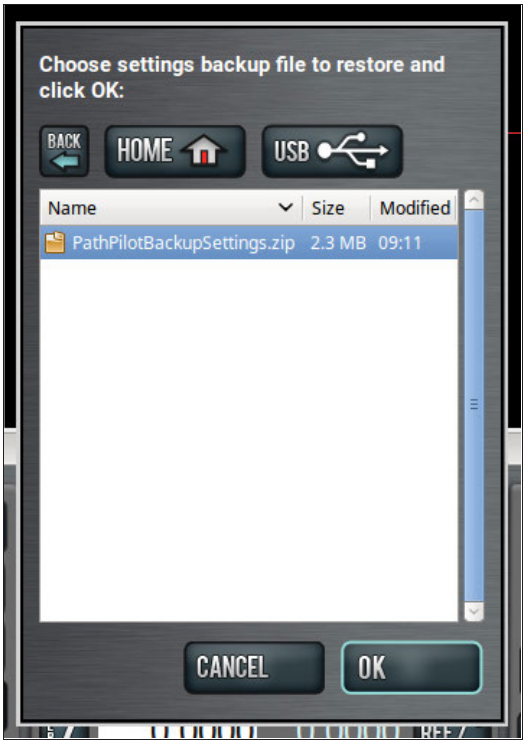

Figure 7-113: Admin Settings Restore dialog box.

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.

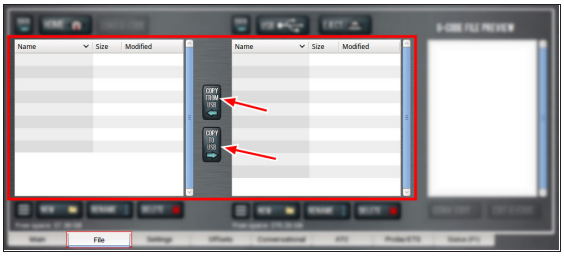

Figure 7-114: USB Files window on the File tab.

> **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.
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.

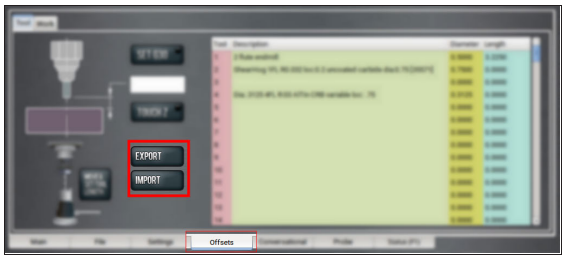

Figure 7-115: Export and Import buttons on the Offsets tab.

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.

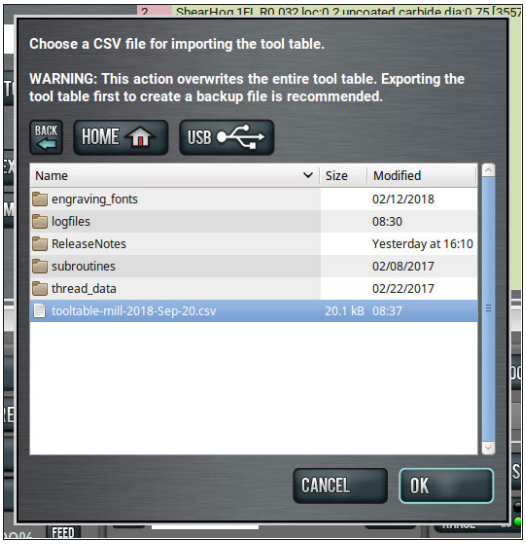

Figure 7-116: Import dialog box.

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.

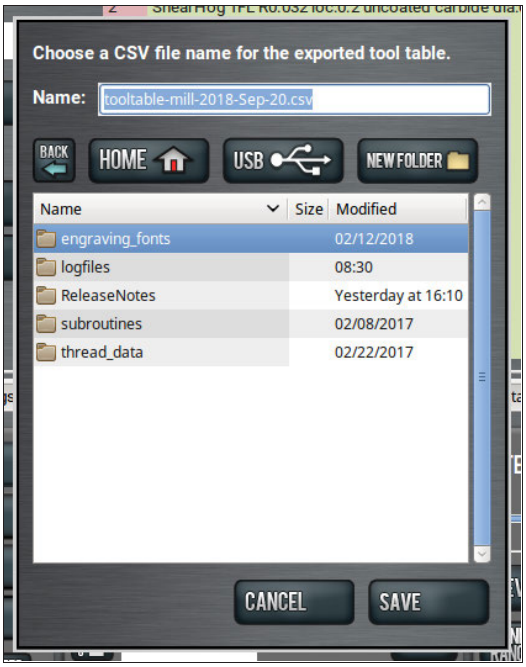

Figure 7-117: Export dialog box.

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.

DRMACH

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 **174**
8.2 Reference the Machine **174**
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8.4 Manually Control the Spindle **176**
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8.6 Set Up Tooling **177**
8.7 Set Tool Length Offsets **178**
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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 Reset button.

8.2 REFERENCE THE MACHINE

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**.

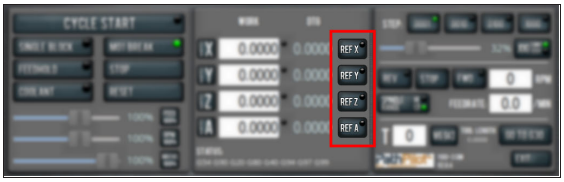


Figure 8-1: Reference buttons.

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" (page 185).

8.2.1 About Referencing

You must reference the machine to establish a known position for PathPilot. The position that's set while referencing the machine is the origin of the machine coordinate system. Without referencing the machine, PathPilot won't know the current position of the machine axes.

You must reference the machine at the following times:

- After you power on the machine
- After you push in the Emergency Stop button
- Before running a G-code program
- Before using MDI commands
- Before setting work or tool offsets
- After a collision or an axis stall/fault

When referencing, the machine moves each axis to the end of its travel. The machine stops at the limit switch, which sets the axis' reference position.

8.3 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.

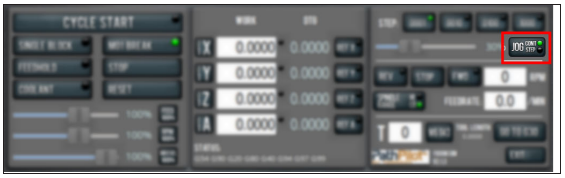


Figure 8-2: Jog button.

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 8-3: Jog Speed slider.

For more information on continuous velocity mode, see "About Continuous Velocity Jogging" (on the next page).

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.

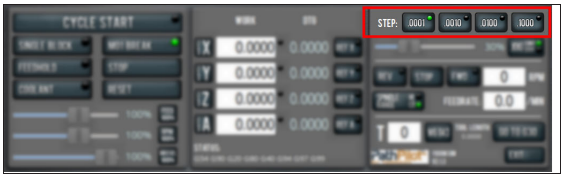


Figure 8-4: Step buttons (in G20 mode).

- 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).

8.3.1 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 or the optional Jog Shuttle. Whether you're jogging with the keyboard or with the Jog Shuttle, 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" (below).

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

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 each time you either press a jog key on the keyboard or click the inner wheel of the Jog Shuttle. 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.

8.3.2 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

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

The optional Jog Shuttle has the following functions:

- An inner wheel and outer ring that jog the currently selected axis.

Rotating either clockwise jogs the axis in the positive direction.
Rotating either counterclockwise jogs the axis in the negative direction.

- Four axis selection buttons, which toggle the currently selected 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.

- A step button, which toggles the selected jog step size.

8.4 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 8-5: 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" (below).
5. Close the spindle motor door.
6. In the **RPM** DRO field, type the desired RPM speed. Then select the **Enter** key.
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.

8.4.1 Change the Spindle Speed Range

To change the spindle speed range, you must move the spindle belt inside of the spindle cabinet:

1. Open the spindle motor door.
2. Unclamp the motor mounting plate: Use an 18 mm wrench to loosen the clamp bolt.
   This allows the spindle motor plate to pivot.
3. Slacken the spindle belt: Pull the pivot handle forward.
4. Move the spindle belt from one set of pulleys to the other.
   Two speed ranges are available:
   - **Low** 175 rpm to 3250 rpm
   - **High** 525 rpm to 10,000 rpm
5. Tighten the spindle belt: Push the pivot handle backward (toward the machine column).
6. Secure the motor mounting plate: Use an 18 mm wrench to tighten the clamp bolt.
7. Firmly push the spindle belt between the pulleys. If it is properly tensioned, the spindle belt should move between 3 mm and 6 mm. If it's not properly tensioned, repeat Steps 2 through 6.
8. Rotate the clamp handle clockwise.
   The spindle motor plate locks in place.
9. Close the spindle motor door.
10. From the PathPilot interface, examine the light on the **Spindle Range** button to make sure that it agrees with the spindle belt's position.

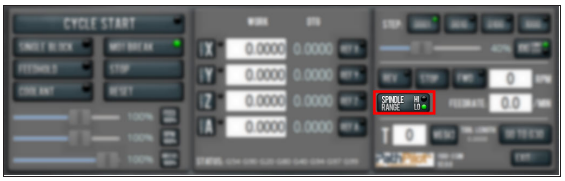


Figure 8-6: Spindle Range button.

8.4.2 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.
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.

8.4.3 Spindle Controls Reference

The spindle speed is measured in revolutions per minute (RPM).

Two speed ranges are available:

- **Low** 175 rpm to 3250 rpm
- **High** 525 rpm to 10,000 rpm

Use the low speed range when you're using larger cutting tools, or machining materials with lower surface speeds (like steel or stainless steel).

Use the high speed range when you're using smaller cutting tools, or machining materials with higher surface speeds (like aluminum, brass, or plastic).

To move your spindle speed range from one to the other, see "Change the Spindle Speed Range" (on the previous page).

8.5 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 122).

To load G-code:

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

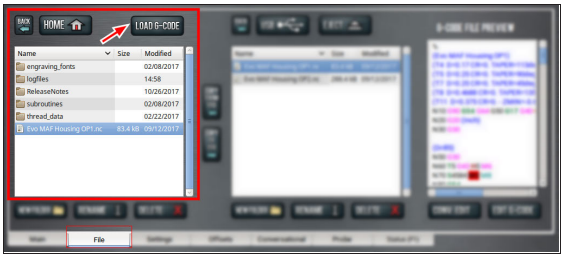


Figure 8-7: Controller Files window on the File tab.

> **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 SET UP TOOLING

The Tormach Tooling System (TTS) allows you to quickly switch between various cutting tools. Before you begin machining, you must put your cutting tools in tool holders and measure the tool length offsets for each tool.

- "Install a Tool in a Set Screw Tool Holder" (page 184)
- "Install a Tool in an ER Collet Tool Holder" (page 184)
- "Install a Drill Chuck in a Jacobs Taper Arbor" (on the next page)

8.6.1 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.

8.6.2 Install a Tool in an ER Collet Tool Holder

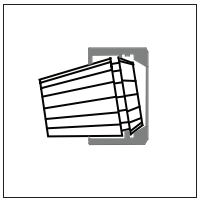
The ER20 collet is self-extracting: the collet must be mounted in the nut before the nut and collet assembly are put into the collet holder.

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).

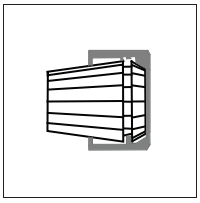
> ***NOTICE!*** If you don't install the collet in the order specified, there's a risk that the collet and/or nut could be damaged, and the collet's holding capacity could be reduced.

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.

8.6.3 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.

8.7 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 170).

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 184).
3. From the PathPilot interface, on the **Offsets** tab, verify that the **Tool** tab is selected.
4. Find the **Tool Table** window.

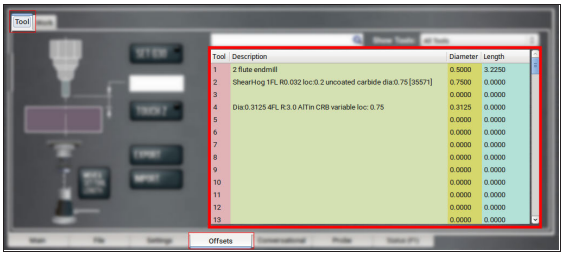


Figure 8-8: Tool Table window on the Offsets tab.

5. Depending on your workflow, you can measure your tools using any of the following methods:
   - **Use a Height Gauge** For information, see "Use a Height Gauge to Measure Tools" (page 180).
   - **Use an Electronic Tool Setter** For information, see "Use an Electronic Tool Setter (ETS) to Measure Tools" (page 180).
   - **Touch Off of a Known Reference Height** For information, see "Touch Off the Tool Length Offsets" (below).

8.7.1 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. To make sure tool length offsets are consistent among your tools, we recommend you use Tormach Tooling System (TTS) tool holders. Set the tool length offset after placing a tool in the Tormach Tooling System (TTS) tool holder — each tool and its tool holder only need to be measured once.

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.

8.7.2 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 **179**
Measure Tools Using a Known Reference Height **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. 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" (on the next page).
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 175).

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.

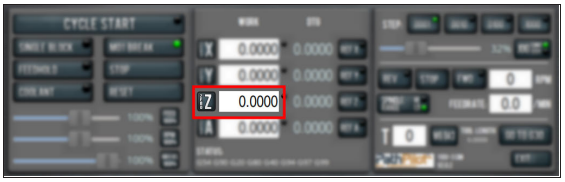


Figure 8-9: Z-axis work offset DRO field.

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" (page 187).

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 8-10: 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.

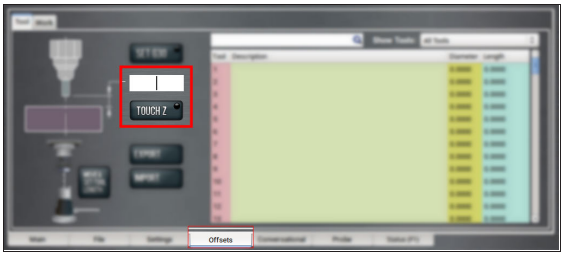


Figure 8-11: Touch Z DRO field and button.

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.

8.7.3 Use an Electronic Tool Setter (ETS) to Measure Tools

An Electronic Tool Setter (PN 31875) is a device used to measure the length of a cutting tool.
To use an ETS to measure tools:

1. Plug in the ETS to the **Accessory 2** port.
2. Put the ETS on the known reference surface below the spindle.
3. From the PathPilot interface, on the **Offsets** tab, in the **Tool Table** window, in the **Description** column, type a description for the tool.
4. In the **Diameter** column, type the diameter of the tool. Then select the **Enter** key.
5. Put a tool holder into the spindle.
6. From the PathPilot interface, type the tool number in the **Tool** DRO field. Then select the **Enter** key.

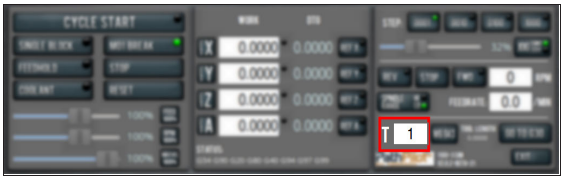


Figure 8-12: Tool DRO field.

7. Jog the Z-axis down (-Z) until it is above the ETS.
8. From the **Offsets** tab, on the **Tool** tab, select **Move and Set Tool Length**.

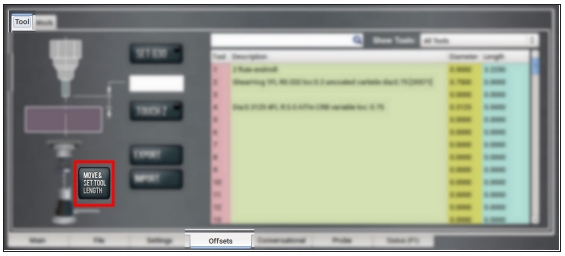


Figure 8-13: Tool tab on the Offsets tab.

> **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).

9. From the **Tool Table** window, in the **Length** column, verify that the length of the tool is correct.

8.7.4 Use a Height Gauge to Measure Tools

1. Before measuring a tool, you must first zero the height gauge using a precision surface, like a Granite Surface Plate (PN 31713): Move the height gauge to the top of the Granite Surface Plate.
2. Press the **Zero** button on the touch trigger.
   The height gauge is zeroed.
3. Insert a tool holder into the Granite Surface Plate.
4. From the PathPilot interface, on the **Offsets** tab, select the **Tool** tab.
5. In the **Tool Table** window, type a description for the tool.
6. Move the height gauge on the Tormach Tool Assistant Set to the end of the tool's cutting edge.
7. Write down the measured tool length, and then type that value into the **Length** column on the **Tool Table** window. Then select the **Enter** key.

8.8 SET WORK OFFSETS

To set the current axis location to zero in the active work coordinate system:

➢ Select **Zero [Axis]**.

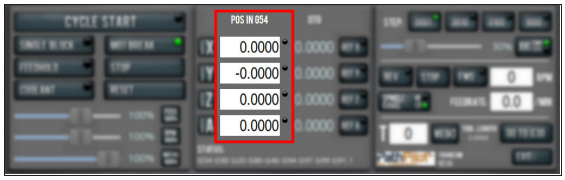


Figure 8-14: Work Offset DRO fields.

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 8-15: 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 186).

8.8.1 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.

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

8.9 OPERATE THE COOLANT PUMP

To turn coolant on or off:

➢ Select **Coolant**.

Figure 8-16: Coolant button.

For more information on turning on and off coolant, see "About Coolant" (below).

8.9.1 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.

FIRST PART TUTORIAL

IN THIS SECTION, YOU'LL LEARN:

- How to complete your first project, with all specifications provided by us.

CONTENTS

9.1 About This Tutorial **184**
9.2 Before You Begin **184**
9.3 Required Items and Tools **184**
9.4 Set Up Tooling **184**
9.5 Set Up the Machine **185**
9.6 Mount the Workpiece **185**
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9.9 Complete the Milling Operations **187**

9.1 ABOUT THIS TUTORIAL

This tutorial project is a shallow circular pocket with the letters PCNC engraved into a 2 in. × 4 in. piece of wood.

Figure 9-1: Example of a completed first part tutorial.

> **Tip!** Using a piece of wood reduces the possibility of damaging a tool if you enter an incorrect work or tool offset.

9.2 BEFORE YOU BEGIN

This tutorial assumes that you have no prior experience running a part program on a computer numerically controlled (CNC) machine. This tutorial will give you an introduction to the controls of the machine using PathPilot.
The two tools used give an introduction to tool changes and the difference between work offsets and tool length offsets. If you have an (optional) Automatic Tool Changer (ATC), we recommend using manual tool changes in this tutorial to keep things simple.

9.3 REQUIRED ITEMS AND TOOLS

Before you begin, collect the following items and tools:

- A scrap piece of wood (at least 2 in. × 4 in. × 4 in.)
- 1/8 in. end mill
- 3/8 in. end mill

  > **Tip!** The Two Flute High-Speed Steel End Mill Set (PN 33465) includes both end mills, and three extra — it's a good set to start with.

- Marker
- TTS Set Screw Holder: 3/8 in. (PN 31820)

> **Tip!** You can also use an ER16 or ER20 collet chuck.

9.4 SET UP TOOLING

The Tormach Tooling System (TTS) allows you to quickly switch between various cutting tools. Before you begin machining, you must put your cutting tools in tool holders and measure the tool length offsets for each tool.

- "Install a Tool in a Set Screw Tool Holder" (below)
- "Install a Tool in an ER Collet Tool Holder" (below)
- "Install a Drill Chuck in a Jacobs Taper Arbor" (page 178)

9.4.1 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.

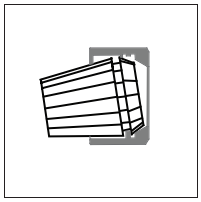
9.4.2 Install a Tool in an ER Collet Tool Holder

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).

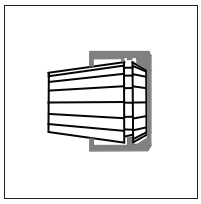
> ***NOTICE!*** If you don't install the collet in the order specified, there's a risk that the collet and/or nut could be damaged, and the collet's holding capacity could be reduced.

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.

9.5 SET UP THE MACHINE

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 Reset button.
2. Verify that the machine can freely move to its reference position (at the ends of travel).
3. 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**.

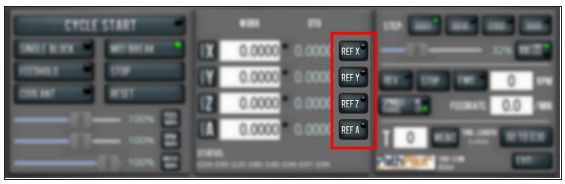


Figure 9-2: Reference buttons.

4. 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, go to "About Referencing" (below).

9.5.1 About Referencing

You must reference the machine to establish a known position for PathPilot. The position that's set while referencing the machine is the origin of the machine coordinate system. Without referencing the machine, PathPilot won't know the current position of the machine axes.

You must reference the machine at the following times:

- After you power on the machine
- After you push in the Emergency Stop button
- Before running a G-code program
- Before using MDI commands
- Before setting work or tool offsets
- After a collision or an axis stall/fault

When referencing, the machine moves each axis to the end of its travel. The machine stops at the limit switch, which sets the axis' reference position.

9.6 MOUNT THE WORKPIECE

- Put a piece of scrap wood (2 in. × 4 in.) in the vise. Make sure that the top of the workpiece is at least 1/4 in. above the top of the vise jaws.

9.7 SET THE WORK OFFSETS

Touch off of the workpiece's center to establish the Z work offsets. Then, use a tool to help you establish the X and Y work offsets.

9.7.1 Set the Z Zero

This procedure sets a new Z zero position for the currently selected work offset.

To set a known reference height:

1. If there's already a tool in the spindle, remove it.
2. Use a marker to mark the approximate center of the workpiece.
3. From the PathPilot interface, in the **Tool** DRO field, type `0`. Then select the **Enter** key.

> **Tip!** It's important that there's no tool in the spindle, and that there's no tool commanded in PathPilot. If a tool was loaded into the spindle, or even commanded in PathPilot, the Z offset would account for the programmed tool length.

4. Slowly jog the Z-axis down (-Z) until it's 0.04 in. (1 mm) from the workpiece.
5. Put a piece of paper on the workpiece.
6. While moving the paper back-and-forth across the workpiece, 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 spindle.

> **Note:** It's easier to use step jogging for this task. For information on step jogging, see "About Step Jogging" (page 175).

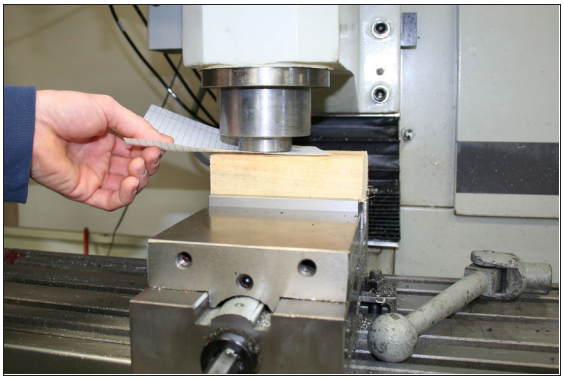


Figure 9-3: Example of using a piece of paper on the workpiece.

7. 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.

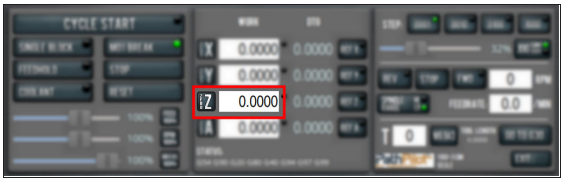


Figure 9-4: Z-axis work offset DRO field.

The reference surface is now set as the Z zero position in the current coordinate system.

9.7.2 Set the X/Y Zeroes

1. Put tool 1 (the 3/8-in. end mill) into the spindle.
2. Jog the tool so that it's close to the mark you put on the workpiece.
3. From the PathPilot interface, select **Zero X**. Then, select **Zero Y**.

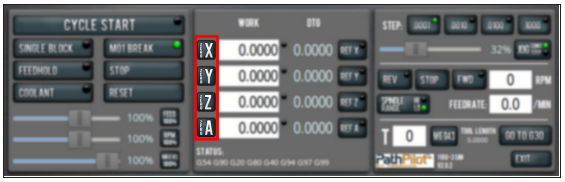


Figure 9-5: Zero X and Zero Y buttons.

9.7.3 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
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

9.7.4 About True Positive Tool Length

To conceptualize tool and work offsets, we use the idea of a true positive tool length. This means that, if you use the face of the empty spindle to set your work offset and touch off your tools, the tool length offsets will be equal in value to the length of the tool.

There are a few benefits to using true positive tool lengths when measuring tool offsets:

- Looking at the tool length value, you can estimate if it's correct for a given tool by checking with a ruler or calipers.
- All of your tools don't have to be measured the same way — you can mix tools touched off on the machine with tools measured using a digital height gauge.
- Conceptually, it's easier to understand.

9.7.5 About X/Y Part Zeroes

Common positions for the X and Y part zeros are:

- The back left of the workpiece
- The center of the workpiece
- A feature, like a hole or a boss, that already exists on the workpiece

9.8 SET TOOL OFFSETS

9.8.1 Touch Off the Tool Offsets

1. Make sure that tool 1 (the 3/8 in. end mill) is in the spindle.
2. In the **Tool** DRO field, type `1`. Then, select **M6 G43**. This tells the machine that you've changed tools, and want to apply the tool length offset.
3. Jog the tool so that it's touching the workpiece.
4. From the PathPilot interface, on the Offsets tab, type `0` in the **Touch** DRO field. Then, select **Touch Z**.

   > **Tip!** If you weren't touching on the top of the workpiece, but instead using a piece of paper between the workpiece and the tool, you would enter the thickness of the paper in the **Touch** DRO field before you selected **Touch Z** to account for the paper thickness.

5. In the **Tool Table** window, identify the length entered for tool 1.
6. Use a calipers to verify that the length for tool 1 is correct.
7. In the **Tool Table** window, type the diameter of the tool. Then select the **Enter** key.

   > **Note:** Fractions are converted to their decimal equivalents.

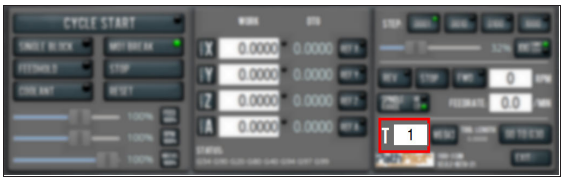
8. Put tool 2 (the 1/8 in. end mill) into the spindle.
9. Repeat Steps 2 through 7 to measure the tool length for tool 2.

9.8.2 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. 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.
2. Put the tool holder into the spindle.
3. From the PathPilot interface, in the **Tool** DRO field, type the number of the tool. Then select the **Enter** key.



4. From the PathPilot interface, on the **Offsets** tab, in the **Tool Table**, select the tool for which you previously wrote a description.
5. Select **Touch Z**.
   The length of the tool is stored in the **Tool Table** window.
6. From the **Tool Table** window, in the **Length** column, verify that the length of the tool is correct.
7. In the **Diameter** column, type the diameter of the tool. Then select the **Enter** key.

9.9 COMPLETE THE MILLING OPERATIONS

There are two milling operations required for this tutorial. Complete the following steps in the order listed:

9.9.1 Create a Pocket **188**

9.9.2 Engrave the Text 189

9.9.1 Create a Pocket

The first step is to mill a pocket into the face of the workpiece that is 0.100 in. deep and 3-1/4 in. in diameter.

Load the Tool

1. Put tool 1 (the 3/8 in. end mill) into the spindle.
2. From the PathPilot interface, in the **Tool** DRO field, type `1`. Then select the **Enter** key.

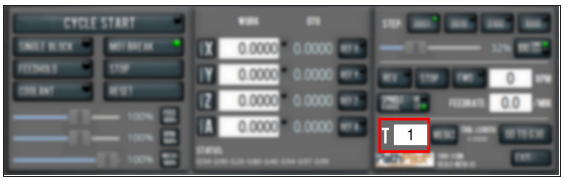


Figure 9-6: Tool DRO field.

Write the G-Code with Conversational

1. From the **Conversational** tab, select the **Pocket** tab.
2. On the **Pocket** tab, select **Rect/Circ**.
   PathPilot switches the interface to create a circular pocket.
3. Type the following values into the DRO fields, and press **Enter** on the keyboard after typing each value:
   a. In the **Title** DRO field, type `FIRST PART POCKET`.
   b. In the **Work Offset** DRO field, type `G54`.
   c. In the **Tool** DRO field, type `1`.
   d. In the **Spindle** DRO field, type `5000`.
   e. In the **Feedrate** DRO field, type `60`.
   f. In the **Z Feedrate** DRO field, type `30`.
   g. In the **Z Clear** DRO field, type `0.1000`.
   h. In the **Pocket Dia.** DRO field, type `3.2500`.
   i. In the **Z Start** DRO field, type `0.000`.
   j. In the **Z End** DRO field, type `-0.1000`.
   k. In the **Z DOC** DRO field, type `0.1000`.
   l. In the **Stepover** DRO field, type `0.2500`.

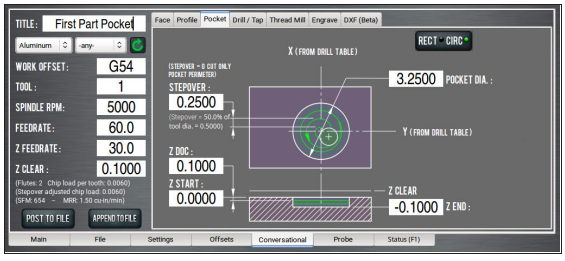


Figure 9-7: Values typed into the DRO fields on the Pocket tab of the Conversational tab.

4. From the **Conversational** tab, select the **Drill/Tap** tab.
5. On the **Drill/Tap** tab, make sure that the **Pattern** tab is selected. Then, type the following values into the following DRO fields:
   a. In the DRO field in the **X** column of row **1**, type `0.0000`. Then select the **Enter** key.
   b. In the DRO field in the **Y** column of row **1**, type `0.0000`. Then select the **Enter** key.

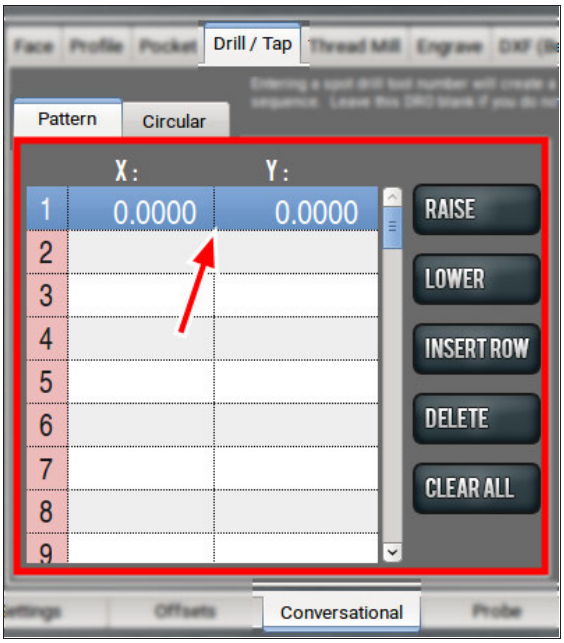


Figure 9-8: Values typed into the DRO fields on the Pattern tab of the Drill/Tap tab.

6. From the **Conversational** tab, select the **Pocket** tab.
7. Select **Post to File**.
   PathPilot generates the G-code file, and the **Save** dialog box displays.

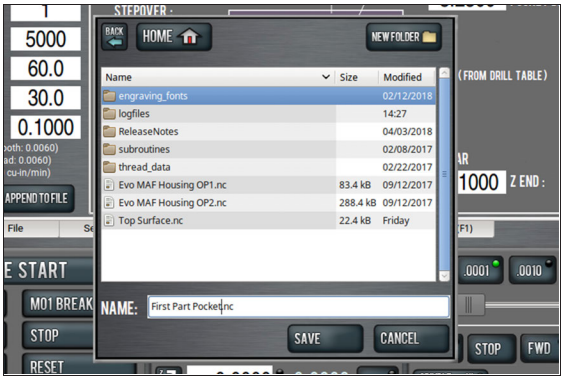


Figure 9-9: Save dialog box.

8. From the **Save** dialog box, specify where on the PathPilot controller to save the G-code file.
9. Select **Save**.
   PathPilot loads the G-code file and opens the **Main** tab.

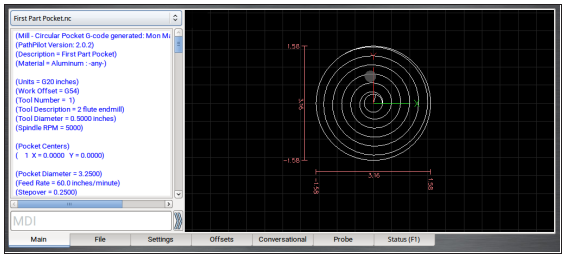


Figure 9-10: Example of the pocket program.

Run the Program

1. Restrict the speed of the mill so that you can more easily watch the operation running: Set the **Maxvel Override** slider to **0%**.

> **Tip!** If you have an optional ATC, this step stops all motion, and prevents the machine from changing tools.

2. Select **Cycle Start**.
   The spindle begins to rotate, but the tool won't move, because you restricted the speed in Step 1.
3. Change the value of the **Maxvel Override** slider to speed up, slow down, or stop the mill. When the tool is close to the part, set the **Maxvel Override** slider to **0%**.
4. On the **Main** tab, verify the values in the DRO fields to make sure that they look correct for the current tool position. Then, slowly move the **Maxvel Override** slider to speed up the mill.

> **E X A M P L E**
> If the value in the **Z** DRO field is **0.2500**, the tool should be 1/4 in. above the workpiece.

5. After the operation is complete, examine the top surface of the workpiece to make sure that the entire pocket has been cut by the end mill.

9.9.2 Engrave the Text

Write the G-Code with Conversational

1. From the PathPilot interface, on the **Engrave** tab, type the following values into the DRO fields, and press **Enter** on the keyboard after typing each value:
   a. In the **Title** DRO field, type `FIRST PART POCKET`.
   b. In the **Work Offset** DRO field, type `G54`.
   c. In the **Tool** DRO field, type `2`.
   d. In the **Spindle RPM** DRO field, type `5000`.
   e. In the **Feedrate** DRO field, type `60`.
   f. In the **Z Clear** DRO field, type `0.1000`.
   g. In the **Text** DRO field, type `PCNC`.
   h. In the **Height** DRO field, type `0.7500`.
   i. In the **X Base** DRO field, type `0.0000`.
   j. In the **Y Base** DRO field, type `-0.3750`.
   k. In the **Z Start** DRO field, type `-0.1000`.
   l. In the **Z Depth** of Cut DRO field, type `0.0500`.

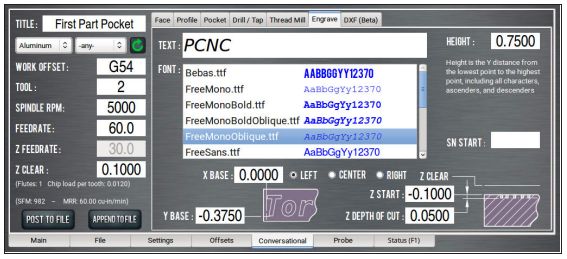


Figure 9-11: Example of the values to type on the Engrave tab of the Conversational tab.

2. From the **Font** list, select **FreeMonoOblique.ttf**.
3. From the **Alignment** radio buttons, select **Center**.
4. Select **Append to File**.
   PathPilot generates the G-code file, and the **Append to File** dialog box displays.

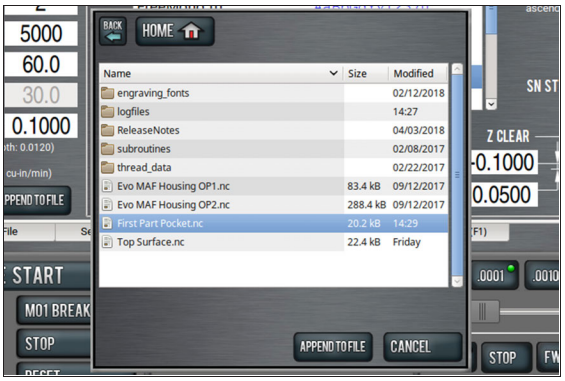


Figure 9-12: Append to File dialog box.

5. From the **Append to File** dialog box, specify to which file you want to add this operation.
6. Select **Append to File**.
   PathPilot adds the G-code to the file and opens the **Main** tab.

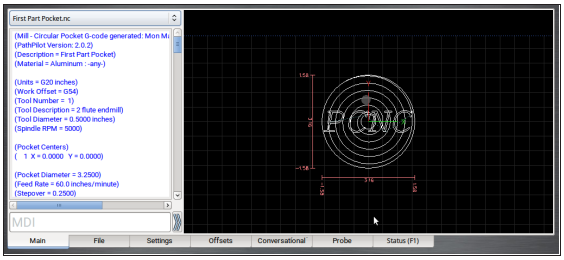


Figure 9-13: Example of the engrave and pocket program.

Run the Program

> **Tip!** Because you appended the second operation onto the first, the program starts from the beginning — it re-cuts the pocket. To avoid this in the future, you can post the second operation to a separate file.

1. Select **Cycle Start**.
   The spindle begins to rotate, and the tool moves to the beginning of the tool path.
2. After the operation is complete, put tool 2 (the 1/8 in. end mill) into the spindle.
3. From the PathPilot interface, in the **Tool** DRO field, type 2. Then select the **Enter** key.
4. Restrict the speed of the mill so that you can more easily watch the operation running: Set the **Maxvel Override** slider to **0%**.
5. Select **Cycle Start**.
   The spindle begins to rotate, and the tool moves to the beginning of the tool path.
6. Change the value of the **Maxvel Override** slider to speed up, slow down, or stop the speed of the mill.
7. After the operation is complete, examine the top surface of the workpiece to make sure that the entire phrase has been engraved by the end mill.

PROGRAMMING

IN THIS SECTION, YOU'LL LEARN:

- About the languages that are understood and interpreted by PathPilot.

CONTENTS

10.1 Programming Overview **192**
10.2 Programming G-Code **197**
10.3 Programming Canned Cycles **208**
10.4 Programming M-Code **212**
10.5 Programming Input Codes **216**
10.6 Advanced Programming **216**

10.1 PROGRAMMING OVERVIEW

Read the following sections for a G-code overview:

10.1.1 About G-Code Programming Language **192**
10.1.2 G-Code Formatting Reference **192**
10.1.3 Supported G-Codes Reference **196**

10.1.1 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).

10.1.2 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)

Programs are limited to 999,999 lines of code.

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. 12 34y 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
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~` is written in an example, the ~ is often referred to as the L number. Similarly the ~ in `H~` 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.

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, 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 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	Commands	Group Description
Group 8	{M07, M08, M09}	Coolant control (special case: `M07` and `M08` may be active at the same time)
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.

10.1.3 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
G07, G08	Diameter / radius mode **Note:** The 15L Slant-PRO lathe and the RapidTurn both use `G07` (X positions displayed in diameter values). `G08` is not used or supported in PathPilot.
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
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
G40	Cancel cutter compensation
G41/G42	Cutter compensation (left/right)
G41.1, G42.1	Dynamic cutter compensation
G43	Apply tool length offset
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

G-Code	Description
G80	Cancel canned cycles
G81	Drilling cycle
G82	Simple drilling cycle
G83	Peck drilling cycle
G85	Boring cycle
G86	Boring cycle
G88	Boring cycle
G89	Boring cycle
G90, G90.1	Arc distance mode
G91, G91.1	Incremental distance mode
G92	Offset coordinates and set parameters
G92.x	Cancel G92, etc.
G93, G94, G95	Feed rate mode
G96, G97	Spindle control mode
G98	Initial level return / R-point level after canned cycles

10.2 PROGRAMMING G-CODE

Read the following sections as a G-code reference:

10.2.1 About the Examples Used **197**
10.2.2 Rapid Linear Motion (G00) **197**
10.2.3 Linear Motion at Feed Rate (G01) **198**
10.2.4 Arc at Feed Rate (G02 and G03) **198**
10.2.5 Dwell (G04) **200**
10.2.6 Set Offsets (G10) **200**
10.2.7 Plane Selection (G17, G18, G19) **202**
10.2.8 Length Units (G20 and G21) **202**
10.2.9 Return to Predefined Position (G28 and G28.1) **202**
10.2.10 Return to Predefined Position (G30 and G30.1) **202**
10.2.11 Automatically Measure Tool Lengths with an ETS (G37 and G37.1) **202**
10.2.12 Straight Probe (G38.x) **203**
10.2.13 Cutter Compensation (G40, G41, G42) **204**
10.2.14 Dynamic Cutter Compensation (G41.1 and G42.1) **205**
10.2.15 Apply Tool Length Offset (G43) **205**
10.2.16 Engrave Sequential Serial Number (G47) **205**
10.2.17 Cancel Tool Length Compensation (G49) **206**
10.2.18 Absolute Coordinates (G53) **206**
10.2.19 Select Work Offset Coordinate System (G54 to G54.1 P500) **206**
10.2.20 Set Exact Path Control Mode (G61) **206**
10.2.21 Set Blended Path Control Mode (G64) **206**
10.2.22 Distance Mode (G90 and G91) **206**
10.2.23 Arc Distance Mode (G90.1 and G91.1) **207**
10.2.24 Temporary Work Offsets (G92, G92.1, G92.2, and G92.3) **207**
10.2.25 Feed Rate Mode (G93, G94, and G95) **207**
10.2.26 Spindle Control Mode (G96 and G97) **208**

10.2.1 About the Examples Used

Many commands require axis words (`X~`, `Y~` ,`Z~`, or `A~`) 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.

10.2.2 Rapid Linear Motion (G00)

For rapid linear motion, program: `G00 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

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

10.2.3 Linear Motion at Feed Rate (G01)

For linear motion at feed rate (for cutting or not), program: `G01 X~ Y~ Z~ A~ F~`

- `X~` is the X-axis coordinate
- `Y~` is the Y-axis coordinate
- `Z~` is the Z-axis coordinate
- `A~` is the A-axis coordinate
- `F~` 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

10.2.4 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.

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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
- `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
```

10.2.5 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

10.2.6 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) **200**
Set Coordinate System (G10 L2) **201**
Set Tool Table (G10 L10) **201**
Set Tool Table (G10 L11) **201**
Set Coordinate System (G10 L20) **201**

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~`

- `P~` is the tool number
- `R~` 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~` is the tool number
- `R~` 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~` is the number of coordinate system to use (G54 = 1, G59.3 = 9)
- `X~` is the X-axis coordinate
- `Y~` is the Y-axis coordinate
- `Z~` is the Z-axis coordinate
- `A~` 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

10.2.7 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.

10.2.8 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.

10.2.9 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~, Y~, and Z~ 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`

Troubleshooting

It's an error if:

- Cutter Compensation is turned on

10.2.10 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

10.2.11 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.

- `P~` 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.

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.
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.

10.2.12 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~ Y~ Z~ A~`
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
```

10.2.13 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

10.2.14 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

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

10.2.15 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

10.2.16 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)

10.2.17 Cancel Tool Length Compensation (G49)

To cancel tool length compensation, program: `G49`

10.2.18 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

10.2.19 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 186).

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).

10.2.20 Set Exact Path Control Mode (G61)

To put the machining system into exact path mode, program: `G61`

10.2.21 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.

10.2.22 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.

10.2.23 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.

10.2.24 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.
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`

10.2.25 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`

10.2.26 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

10.3 PROGRAMMING CANNED CYCLES

Read the following sections for reference:

10.3.1 Canned Cycles Reference **208**
10.3.2 High Speed Peck Drill (G73) **209**
10.3.3 Cancel Canned Cycles (G80) **210**
10.3.4 Drilling Cycle (G81) **210**
10.3.5 Simple Drilling Cycle (G82) **211**
10.3.6 Peck Drilling Cycle (G83) **211**
10.3.7 Tapping Cycle (G84) **211**
10.3.8 Boring Cycle (G85) **211**
10.3.9 Boring Cycle (G86) **212**
10.3.10 Boring Cycle (G88) **212**
10.3.11 Boring Cycle (G89) **212**

10.3.1 Canned Cycles Reference

Supported Canned Cycles

Canned Cycle	Description
`G80`	Cancel active canned cycle
`G81`	Simple drilling cycle
`G82`	Simple drilling with dwell cycle
`G83`	Peck drilling cycle
`G73`	High speed 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.

10.3.2 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

10.3.3 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.**"

10.3.4 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.

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
```

10.3.5 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.

10.3.6 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

10.3.7 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
```

10.3.8 Boring Cycle (G85)

The `G85` cycle is intended for boring or reaming, but could be used for drilling or milling.

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.

10.3.9 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

10.3.10 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.

10.3.11 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.

10.4 PROGRAMMING M-CODE

Read the following sections for reference:

10.4.1 Supported M-Codes Reference **212**
10.4.2 Program Stop and Program End (M00, M01, M02, and M30) **213**
10.4.3 Spindle Control (M03, M04, and M05) **214**
10.4.4 Tool Change (M06) **214**
10.4.5 Coolant Control (M07, M08, and M09) **214**
10.4.6 Override Control (M48 and M49) **214**
10.4.7 Feed Override Control (M50) **214**
10.4.8 Spindle Speed Override Control (M51) **214**
10.4.9 Set Current Tool Number (M61) **215**
10.4.10 Set Output State (M64 and M65) **215**
10.4.11 Wait on Input (M66) **215**
10.4.12 USB Camera Control (M301, M302, M303) **215**

10.4.1 Supported M-Codes Reference

M-Code	Description
M00	Program stop
M01	Optional program stop
M02	Program end
M03, M04	Rotate spindle clockwise/counterclockwise
M05	Stop spindle rotation
M07, M08	Coolant on
M09	All coolant off

M-Code	Description
M30	Program end and rewind
M48	Enable speed and feed override
M49	Disable speed and feed override
M64	Activate output relays
M65	Deactivate output relays
M66	Wait on an input **Note:** M64 through M66 is only useful with a USB M-Code I/O Interface Kit (PN 32616).
M98	Call subroutine
M99	Return from subroutine/repeat
M301, M302, M303	USB camera control

10.4.2 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)
- 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 146).

10.4.3 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.

10.4.4 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
```

10.4.5 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.

10.4.6 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.

10.4.7 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).

10.4.8 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.

10.4.9 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

10.4.10 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
```

10.4.11 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.

10.4.12 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 146).

10.5 PROGRAMMING INPUT CODES

Read the following sections for reference:

10.5.1 Feed Rate (F) **216**
10.5.2 Spindle Speed (S) **216**
10.5.3 Change Tool Number (T) **216**

10.5.1 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.

10.5.2 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

10.5.3 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

10.6 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 — i'ts difficult to debug, and difficult for another operator to understand. Modern CAM virtually eliminates the need for it.
Read the following sections for reference:

10.6.1 Parameters **216**
10.6.2 Expressions **218**
10.6.3 Subroutines **219**

10.6.1 Parameters

Read the following sections for reference:

Parameters Reference **216**
Numbered Parameters Reference **217**
Subroutine Parameters Reference **218**
Named Parameters Reference **218**

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)

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- 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 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.

10.6.2 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 Reference **218**
Functions Reference **219**

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

10.6.3 Subroutines

Subroutines are subprograms that are called from inside another program.

Read the following sections for reference:

Subroutines Reference **219**
Conditional Subroutines Reference **220**
Repeating Subroutines Reference **221**
Looping Subroutines Reference **221**

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**.

> **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 theif 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, than 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 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
- 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

DRMACH

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

11.1 Maintenance Safety **224**
11.2 Maintenance Schedules **224**
11.3 Regular Maintenance **225**

11: MACHINE MAINTENANCE

11.1 MAINTENANCE SAFETY

Read and understand the following safety messages before beginning any maintenance procedures.

11.1.1 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+.

11.1.2 Swarf Maintenance Procedures

- Wear work gloves.

11.1.3 Coolant Maintenance Procedures

- Wear rubber gloves.

11.2 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" (above).

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 257). 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.

11.2.1 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.

- ☐ If you have pneumatic accessories installed (like a Power Drawbar), verify that the regulator has at least 90 psi compressed air.
- ☐ Verify that the door switches are properly functioning.

11.2.2 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.
- ☐ Examine the Tormach Tooling System (TTS) collet 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.

11.2.3 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.

11.2.4 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.

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11.2.5 Annually

- ☐ Verify that the limit switches are properly functioning.
- ☐ 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.

11.3 REGULAR MAINTENANCE

11.3.1 Clean the Way Covers **225**
11.3.2 Clean the Coolant System **225**
11.3.3 Examine the Drawbar **226**
11.3.4 Examine the Enclosure Windows **226**
11.3.5 Lubricate the Machine **226**
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11.3.8 Prevent Rust **227**

11.3.1 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.

11.3.2 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.
- Use a Floating Tramp Oil Collection Pillow (PN 31925) or an oil skimmer to remove tramp way oil from the coolant tank.

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.

11.3.3 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.
- Use Anti-Seize (PN 31273) to lubricate the following items:
  - Drawbar threads
  - Thrust shoulder of the drawbar
  - Drawbar's thrust washer

If you have an (optional) Power Drawbar, regularly do the following:

- Use Anti-Seize to lubricate the Power Drawbar disc springs (the Belleville washers) and clamping mechanism.
- Tighten the drawbar until it is as tight as possible while still releasing a Tormach Tooling System (TTS) tool holder using 90 psi (620 kPa) compressed air.

11.3.4 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)

11.3.5 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

The automatic oiler is powered whenever the machine is powered on, and has the following default settings:

- Lubrication interval: 480 minutes (8 hours)
- Actuation time: 12 seconds

Lubrication System Reference

The machine's lubrication system distributes oil to the following 15 points:

- 12 slideways bearing surfaces
  - Four on the X-axis
  - Four on the Y-axis
  - Four on the Z-axis
- Three ball screw nuts

11.3.6 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).

11.3.7 Examine the Tormach Tooling System (TTS) Collet

To extend the service life of the Tormach Tooling System (TTS) collet, you must regularly do the following:

- Examine the Tormach Tooling System (TTS) collet for signs of wear or damage.
- Make sure the inside of the Tormach Tooling System (TTS) collet is clean and dry.
- Use Anti-Seize (PN 31273) to lubricate the outside of the Tormach Tooling System (TTS) collet and the inside of the spindle taper.
- Use a mild degreaser to clean the shank of all tool holders.

11.3.8 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 225)).
- 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.

DRMACH

TROUBLESHOOTING

IN THIS SECTION, YOU'LL LEARN:

- About common causes of failure in this machine, and our recommendations for diagnosing and correcting them.

WARNING! Electrocution Hazard - Electrical Cabinet: Do not make or disconnect connections under power.

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

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12: TROUBLESHOOTING

12.1 TROUBLESHOOTING SAFETY

Read and understand the following safety messages before beginning any troubleshooting procedures.

- Take things slow and be extra cautious. During troubleshooting, you're exposed to more hazards than during normal operation. For example, you may have to do an electrical test on a live circuit, remove guards, or override a safety switch to make an observation.
- Power off the machine and disconnect the pneumatic supply before doing any troubleshooting procedures.
- When appropriate, lockout/tagout the Main Disconnect switch and the pneumatic supply line before doing any troubleshooting procedures.

12.2 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 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)

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

12.3 REQUIRED TOOLS

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

- #2 Phillips screwdriver
- #3 Phillips screwdriver

- 1/8 in. flat-blade screwdriver
- 3/16 in. flat-blade screwdriver
- Digital multimeter that can test for:
  - Vac volts (up to 300 Vac)
  - Vdc volts (up to 100 Vdc)
  - Resistance (from 0 to 1M ohms)
  - Hz (frequency)
- Electrical safety gloves
- Measuring tools (like a tape measure, calipers, or dial indicator with magnetic base)
- Needle nose pliers
- Trouble light, headlamp, or flashlight
- Wire stripper

12.4 FREQUENTLY FOUND PROBLEMS

There are several frequently found problems with all electromechanical machinery. Among the problems that have occurred, we've found that the following are more frequent than others:

- **Loose Wires**

  > **Note:** Before you begin the two-finger pull test, we recommend taking photos of the inside of the electrical cabinet to serve as a visual reference while reconnecting any loose wires.

  To determine if a wire is loose, use the two-finger pull test:

  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. With your thumb and index finger, hold the wire close to its termination point, and gently tug each wire.
  3. If the wire comes loose, re-terminate and reconnect it before moving on to other wires.

- **Poor Cable Connections**

  An improperly seated cable may allow some functions to work but cause others not to. We have found that the ribbon cables' plug connections can become loose during the shipping process.

  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. Unplug and firmly reseat connectors.

- **Limit Switches**

  The X- and Y-axes have one limit switch located mid-travel, which actuates at the end of travel in each direction. The Z-axis has one limit switch located at the upper limit of motion.

  To learn more about the limit switches, see "Axes Drive Subsystem" (page 235).

12.5 ELECTRICAL SERVICE

> ⚠ **WARNING!** Electrocution Hazard: When servicing the machine from inside the electrical cabinet, always use caution. Points in the electrical cabinet have high voltages that can electrocute or shock you. Even after you've powered off the machine, electronic devices in the electrical cabinet may retain dangerous electrical voltages. Only qualified electrical machinery technicians should perform maintenance or troubleshooting procedures inside the electrical cabinet while power is still on.

Many electrical problems are self-apparent, and you can trace them by observing LEDs in PathPilot, LEDs in the electrical cabinet, and the machine's actions.

LEDs in PathPilot indicate output or functional status — including the LEDs on the Status tab, which are useful for indicating if any inputs are operational.

There are various LED indicators in the electrical cabinet. Among these are:

- **Bus Board DC Power LED** Indicates voltage on the DC-BUS board, power to axis drivers.
- **Axis Driver Power Indicators on the X-, Y-, Z-, and A-Axis Drivers** Green indicates power to each individual drive, red indicates a fault.
- **Control Board DS3** Indicates power to the control board.
- **Control Board DS8** Indicates that the PathPilot controller is ready.
- **Control Board DS9** When on, indicates that the machine is ready.
- **Control Board DS10/DS11** When DS11 is on and DS10 is flashing, indicates an Ethernet connection to the PathPilot controller.

12.6 POWER DISTRIBUTION SUBSYSTEM

Electrical power is run through a single power cord to the Main Disconnect switch. This switch controls all power to the machine, the coolant pump, and the PathPilot controller.

To troubleshoot the power distribution subsystem, read the following:

12.6.1 The Controller Won't Power On **232**
12.6.2 The Coolant Pump Won't Run **233**

12.6.1 The Controller Won't Power On

Cause: The PathPilot controller isn't plugged in to an outlet.		
Probability	**How-To Steps**	**Need More?**
High	➢ Reseat the power cord connection at both the outlet and the controller.	It's possible that the power cord could become loose from movement.

Cause: The CB3 circuit breaker tripped.		
Probability	**How-To Steps**	**Need More?**
Medium	➢ If the monitor and the controller both don't have power, examine the power cords for damage or exposed wires, and then reset the CB3 circuit breaker.	CB3 affects the monitor and the controller.

Cause: The video cable is disconnected from the PathPilot controller.		
Probability	**How-To Steps**	**Need More?**
Low	➢ Reseat the video cable connection at both the monitor and the PathPilot controller.	If the monitor is disconnected, it could seem like a controller power issue.

12.6.2 The Coolant Pump Won't Run

Cause: Fuse F1 on the machine control board is blown.		
Probability	**How-To Steps**	**Need More?**
Medium	1. Unplug the coolant pump power cord and examine it for damage. 2. Use a digital multimeter to verify the motor's winding-to-winding and winding-to-ground resistances. If any winding-to-winding resistance measurement is a short (near zero resistance) or an open circuit or if the winding-to-ground resistance is a short, the coolant pump must be replaced. 3. Replace the fuse with a 3A slow-blow fuse, power on and reset the machine, and select the **Coolant** button in PathPilot. Use a digital multimeter to test the power at the XS2 receptacle. If the fuse blows again with the pump plugged in, replace the pump.	If the coolant pump shorts, the 3 A, slow-blow, F1 flood coolant fuse on the ECM1 control board blows before CB3 trips.

Cause: The coolant pump isn't plugged in to an outlet.		
Probability	**How-To Steps**	**Need More?**
Low	➢ Examine the connection at the outlet.	It's possible that the power cord could become loose from movement.

Cause: The coolant control relay on the machine control board failed.		
Probability	**How-To Steps**	**Need More?**
Low	1. From the PathPilot interface, toggle the **Coolant** button to **On**. 2. Examine the coolant receptacle for power. If there's no power, and fuse F1 has continuity, it's likely that the K3 relay failed. 3. Power off the machine (see "Power Off the Machine" (page 52)). Then, install a short jumper between wires J5-1 and J5-2. 4. Power on the machine (see "Power On the Machine" (page 51)). If the pump runs when the machine is powered on, replace the machine control board.	1. Power off the machine (see "Power Off the Machine" (page 52)). Then, install a short jumper between wires 109 and 125 on the machine control board. 2. Power on the machine (see "Power On the Machine" (page 51)). If the pump runs when machine is powered on, it's likely that the problem is the K3 relay. **Note:** This relay will fail if too high of a current draw passes through it. This is common when electrical loads much larger than the coolant pump are plugged into the coolant outlet.

12.7 CONTROL POWER SUBSYSTEM

To troubleshoot the control power subsystem, read the following:

12.7.1 The Machine Won't Power On **234**

12.7.1 The Machine Won't Power On

Cause: The Emergency Stop button is pushed in.		
Probability	**How-To Steps**	**Need More?**
High	➢ Twist out the Emergency Stop button and press the Reset button.	The Reset button doesn't illuminate until after you: 1. Twist out the Emergency Stop button. 2. Press the Reset button.

Cause: The DC power supply PS1 is defective.		
Probability	**How-To Steps**	**Need More?**
Medium	➢ Measure for 24 Vdc nominal between wires 401 and 400.	Before you replace the DC power supply, power off the machine (see "Power Off the Machine" (page 52)).

Cause: The Main Disconnect switch is in the Off position.		
Probability	**How-To Steps**	**Need More?**
Low	➢ Examine the Main Disconnect switch. If it's not already in the On position, turn it on.	If needed, measure for 115 Vac nominal between wires 101 and 100/N.

Cause: The mains breaker is turned off.	
Probability	**How-To Steps**
Low	➢ Examine the breaker. If it's not already on, turn it on.

Cause: The CB1 and/or CB2 circuit breaker tripped.		
Probability	**How-To Steps**	**Need More?**
Low	1. Measure for 115 Vac nominal between wires 105 and 100/N. 2. Measure for 115 Vac nominal between wires 107 and 100/N.	Before you reset the tripped breaker, power off the machine (see "Power Off the Machine" (page 52)).

Cause: The contactor K1 is defective.		
Probability	**How-To Steps**	**Need More?**
Low	• If the contactor's red LED is on, the contactor is latched. Use a digital multimeter to examine the power at K1-1 and wire 115. • If the contactor's LED is not on, press and hold the Reset button and observe the LED on K1: ◦ If it's on, K1 has a latching circuit issue. ◦ If it's not on, K1 may have a coil issue.	Contactor K1 energizes the DC-BUS board, which provides 65 Vdc to the machine. K1 can fail by not energizing the coil, or the contacts could fail.

12.8 AXES DRIVE SUBSYSTEM

The axis motors are used to move the X-, Y-, Z-, and A-axis. The motors are powered by electronic driver modules (also referred to as axis drivers) which receive control signals from the control board. The electronic driver modules are powered by the DC-BUS board. Travel limits are established by limit switches when the machine is referenced.
To troubleshoot the axes drive subsystem, read the following:

12.8.1 All Axes Won't Move When Commanded **236**
12.8.2 One Axis Won't Move (or Only Moves in One Direction), and Other Axes Move **236**
12.8.3 Axis Movement is Noisy **239**
12.8.4 Can't Reference All Axes **241**
12.8.5 Lost Motion on Axis Travel **243**

12.8.1 All Axes Won't Move When Commanded

Cause: Control signals aren't reaching the electronic driver modules.		
Probability	**How-To Steps**	**Need More?**
High	1. Power off the machine (see "Power Off the Machine" (page 52)). 2. Examine the connectors at the J6 connection at the machine control board, and the ribbon cables at the axes drivers: a. Remove the connectors, and inspect them for any bent pins or discoloration. b. Firmly reseat the connectors.	Examine the ribbon cable 423 from the control board (J6) to the axes motors.

Cause: The DC-BUS board is malfunctioning.		
Probability	**How-To Steps**	**Need More?**
Medium	The loss of DC-BUS board power to one or more axes is likely if the axes driver LEDs are not on, if they're dim, or if they're a color other than green. ➢ Examine the axis status LEDs on the axis drivers.	For information, see "There's a blown fuse on the DC-BUS board" in "One Axis Won't Move (or Only Moves in One Direction), and Other Axes Move" (below).

Cause: PathPilot isn’t commanding the move, or there's a controller problem.	
Probability	**How-To Steps**
Low	1. Jog the axes and, from the PathPilot interface, examine the value displayed in their DRO fields. If the position doesn't change while you're jogging, there's a problem with the controller. 2. Select the Main tab, then, on the keyboard, select the **Esc** key. 3. Try to jog the axes again, and examine the value displayed in their DRO fields. 4. If the problem persists, restart the controller.

12.8.2 One Axis Won't Move (or Only Moves in One Direction), and Other Axes Move

Cause: There are loose wires or ribbon cables.	
Probability	**How-To Steps**
High	1. Power off the machine (see "Power Off the Machine" (page 52)). 2. Examine the connection of the J6 ribbon cable and the power wires from the DC-BUS board to the affected driver. 3. Power on the machine (see "Power On the Machine" (page 51)) and test for operation.

Cause: There's a defective or malfunctioning axis driver.

Probability	How-To Steps	Need More?
Medium	1. Power off the machine (see "Power Off the Machine" (page 52)). 4. On the malfunctioning axis driver, replace the ribbon cable connector for the control signals and the motor/DC supply connector with those from a functioning axis driver. 6. Power on the machine (see "Power On the Machine" (page 51)). 7. Jog the malfunctioning axis in both directions. If the malfunctioning axis now moves properly, then it's likely that the malfunctioning axis driver is defective. 8. Jog the functioning axis in both directions. A defective malfunctioning axis driver is confirmed if the previously functioning axis has the same problem.	Swapping control signals between axis drivers is very helpful during troubleshooting (there are at least three identical axis drivers in this subsystem). **Note:** If control signals are switched from the driver on the non-functioning axis to a driver on a functioning axis, the end of travel limit switch on the non-functioning axis won't work. Take care to avoid reaching the end of travel when moving an axis.

Cause: There's a blown fuse on the DC-BUS board.

Probability	How-To Steps	Need More?
Medium	1. Power off the machine (see "Power Off the Machine" (page 52)). 2. Remove the cover from the DC-BUS board. 3. Measure the continuity on each fuse with a multimeter. Then, visually inspect each fuse. If a fuse is blown, replace it with an equivalent fuse.	A blown fuse usually is the result of a defective drive or wiring. Inspect the axis' wiring carefully and repair any damage observed. If you replace a fuse and it immediately blows, it's likely a defective axis drive or its wiring.

Cause: There's a loose axis motor coupling.

Probability	How-To Steps
Low	• Jog the axis and listen to determine if you can hear the motor run. • Remove the cover plate over the coupling and make witness marks to determine if the motor's turning but the screw isn't.

Cause: There's a defective motor or motor connection.

Probability	How-To Steps	Need More?
Low	1. Power off the machine (see "Power Off the Machine" (page 52)). 4. Remove the motor leads from the axis driver, and examine the motor for signs of coolant contamination. 5. Measure the resistance of windings at the green connector on the axis driver (see "Motor Resistance Reference" (on the next page)). 6. If the resistance is out of range, carefully check the wiring: a. Locate the axis motor connector near the motor and repeat the resistance test. b. If the resistance is out of spec again, then the motor is defective. c. If the resistance is within spec, then inspect the cable and connectors between the axis motor and axis driver.	When making resistance measurements on motors and other devices with low resistance, always take a tare reading on the meter before doing the resistance measurement on the motor or device.

Cause: The gibs are too tight or too loose.

Probability	How-To Steps	Need More?
Low	➢ Adjust the gibs.	Gibs that are too tight result in too much friction in the ways. Gibs that are too loose can cause binding.

Cause: Oil isn't getting to the ways and ball screw.

Probability	How-To Steps
Low	1. Examine the oil level in the oiler. 2. Investigate the oiling system for lack of oil and/or plugged lines (See Tormach service bulletin SB0031).

Cause: There's oil residue from long-term storage.

Probability	How-To Steps
Low	➢ Repeatedly pump oil and slowly jog the axis.

Cause: There's debris on the ball screw.

Probability	How-To Steps	Need More?
Low	➢ Clean the ball screw.	Debris on the ball screws can rapidly accelerate wear and reduce the lifespan of your machine. Evaluate if additional measures are required to protect your machine's ball screws and ways (like supplemental dust collection).

Cause: There's a thermal trip or an electrical short on an axis driver.	
Probability	**How-To Steps**
Low	1. Examine the LEDs on the axis drivers. If there's a red LED on the driver, that means it's tripped. 2. Power the machine on and off, and the trip should reset. 3. If the problem continues, examine the wiring for shorts and test the motor resistance. (For more information, see "There's a defective motor or motor connection." earlier in this section.) 4. If the problem continues, replace the axis driver.

Motor Resistance Reference

X-, Y-, Z-Axis		Resistance
From (black probe)	To (red probe)	
212/222/232	213/223/233214/224/234	0.5-2.0 Ω 0.5-2.0 Ω >1 M Ω
214/224/234	213/223/233	0.5-2,0 Ω 1 M Ω
All wires above	Ground bar	>1 M Ω

Note: Resistance across leads on all phases for X, Y and Z should be about the same. Deviation may indicate a problem. This does not apply to the A-axis.

DC-BUS Power Distribution Reference

The DC-BUS board contains four fuses which are used to individually fuse power to the axes drivers. A fifth fuse is provided on the supply boards for the Z-axis brake. Fuses are noted on the circuit board. Note that the control power circuit must be on.

Fuse Number on DC-BUS Board	Function	Wire Numbers to Monitor (Common Lead (0V) Listed First)	Voltage When DC-BUS is OK and When Fuse is Good
F1 X	X-axis	210 211	55-75 Vdc
F2 Y	Y-axis	220 221	55-75 Vdc
F3 Z	Z-axis	230 231	55-75 Vdc
F4 A	A-axis	240 241	55-75 Vdc

12.8.3 Axis Movement is Noisy

Before You Begin

WARNING! Electrocution Hazard: When servicing the machine from inside the electrical cabinet, always use caution. Points in the electrical cabinet have high voltages that can electrocute or shock you. Even after you've powered off the machine, electronic devices in the electrical cabinet may retain dangerous electrical voltages. Only qualified electrical machinery technicians should perform maintenance or troubleshooting procedures inside the electrical cabinet while power is still on.

Some procedures in this section require servicing the machine from inside the electrical cabinet. Before you begin, you must identify a qualified electrical machinery technician to perform the procedures.

Cause: There's a loose wire connection or failed connector.

Probability	How-To Steps	Need More?
High / Low	➢ Power off the machine (see "Power Off the Machine" (page 52)). Then, tighten all screw connections.	Examine the green power connector for signs of overheating.

Cause: There's a defective axis driver module.

Probability	How-To Steps	Need More?
Medium	➢ See "One Axis Won't Move (or Only Moves in One Direction), and Other Axes Move" (page 236).	There have been cases of a noisy axis relating to a defective axis driver. This may be temperature-dependent.

Cause: There's loose sheet metal.

Probability	How-To Steps	Need More?
High	➢ Feel for vibrating sheet metal.	Loose sheet metal is mistakenly diagnosed as a noisy axis motor. On some systems, certain axis motor speeds can cause audible vibration.

Cause: The C1 (DC-BUS) capacitor is defective.

Probability	How-To Steps
Low	1. Power off the machine (see "Power Off the Machine" (page 52)). Then, unplug the green power connectors on all of the axis drivers (X, Y, Z, and A). 2. With the electrical cabinet door open, power on the machine (see "Power On the Machine" (page 51)). 3. Examine the green LED on the DC-BUS board, and then twist out the Emergency Stop button and press the Reset button. The green LED should come on. 4. Push in the Emergency Stop button. If the LED goes out in two seconds or less, the capacitor is defective and must be replaced. If the LED takes five seconds or more to go out, the capacitor is OK. 5. If the results are not conclusive, power off the machine (see "Power Off the Machine" (page 52)). Then, unplug the green power connectors from the axis drivers (if they're not already unplugged). 6. Power on the machine (see "Power On the Machine" (page 51)). Then, carefully measure DC voltage on wires 202 (common) and 203 on the DC-BUS board. If there's a DC voltage of a nominal 65 Vdc (55-75), this indicates the capacitor is OK. If there's a DC voltage of a nominal 40 Vdc (35-45), this indicates the capacitor is defective.

12.8.4 Can't Reference All Axes

Cause: The machine must be reset.		
Probability	**How-To Steps**	**Need More?**
High	➢ From the PathPilot interface, select **Reset**.	For information, see "Bring the Machine Out of Reset" (page 155) and "About Reset Mode" (page 155).

Cause: The machine is stuck on a limit switch.		
Probability	**How-To Steps**	**Need More?**
High	➢ From the PathPilot interface, on the **Status** tab, examine the axes' **Limits** LEDs. If one or more LEDs are on, do the following: 1. Identify which axis is stuck on a limit switch. 2. From the PathPilot interface, on the **Settings** tab, clear the **Limit Switches** checkbox. Then, on the dialog box, select **OK**. 3. Jog the axis away from the limit switch that it's on. 4. From the PathPilot interface, on the **Settings** tab, select the **Limit Switches** checkbox to re-enable the limit switches.	If an axis is moved before referencing the machine, it can trigger a limit switch and become stuck. When you disable the limit switches, 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.

Cause: A limit switch is defective.		
Probability	**How-To Steps**	**Need More?**
Low	1. Go to "The machine is stuck on a limit switch." earlier in this section. 2. Examine each limit switch for its red LED. If any of the limit switch's red LEDs is off, go to "A limit switch's cable or connector is defective." later in this section.	Each limit switch has a red LED that illuminates whenever the machine is powered on.

Cause: A limit switch's cable or connector is defective.		
Probability	**How-To Steps**	**Need More?**
Low	1. Power off the machine (see "Power Off the Machine" (page 52)). 2. Inspect and reseat the limit switch's connectors on both ends of the cable. 3. Inspect the limit switch's cable for wear or damage.	Each limit switch's cable is routed from the machine control board to the limit switch, and it has a connector on each end.

Cause: A limit switch flag is improperly adjusted.		
Probability	**How-To Steps**	**Need More?**
Low	If the machine crashes into the hard stop during the referencing procedure: 1. Jog the machine to its reference position. 2. From the PathPilot interface, on the **Settings** tab, clear the **Limit Switches** checkbox. Then, on the dialog box, select **OK**. 3. Push in the Emergency Stop button on the operator box. 4. Adjust the limit switch flag so that the limit switch's red LED is off. 5. Jog the machine off of the limit switch. 6. From the PathPilot interface, on the **Settings** tab, select the **Limit Switches** checkbox to re-enable the limit switches. For information, see "The machine is stuck on a limit switch." earlier in this section.	If the limit switch flags are improperly adjusted, the limit switch won't trigger when the machine is referenced. Instead, the axis will crash into the hard stop.
Cause: The control board is defective.		
Probability	**How-To Steps**	**Need More?**
Low	➢ Go to "Limit Switch Function Reference" (below).	A defective control board will report no change in the state of the limit switch, even though the switch and wiring are functioning properly.

Limit Switch Function Reference

Input Status Reported from the Status Tab	Test to Perform on Wiring at the Machine Control Board	Results and Conclusions
The **X Limit** light is always on, even though the switch is not actuated.	Jumper wires 409 to 414 on the machine control board.	• If the light doesn't go out when the terminals are jumped, the machine control board is defective. • If the light goes out when the terminals are jumped, the wiring has a break or the limit switch is defective. • If the diagnostic light is off, the wiring is OK and the switch is defective. • If the diagnostic light is on, the wiring has a break or defective connection.
The **Y Limit** light is always on, even though the switch is not actuated.	Jumper wires 410 to 414 on the machine control board.	
The **Z Limit** light is always on, even though the limit switch is not actuated.	Jumper wires 411 to 414 on the machine control board.	

Input Status Reported from the Status Tab	Test to Perform on Wiring at the Machine Control Board	Results and Conclusions
The **X Limit** light is never on, even though the switch is actuated.	Remove wire 409 on the machine control board.	• If the light doesn't go on when the wire is removed, the machine control board is defective. • If the light goes on when wire is removed, the wiring has a short or the limit switch is defective: 1. Power off the machine (see "Power Off the Machine" (page 52)). Then, disconnect wires from the switch and tape the end of each wire to prevent shorts. 2. Power on the machine (see "Power On the Machine" (page 51)). 3. If the diagnostic light is on, the wiring is OK and the switch is defective. 4. If the diagnostic light is off, the wiring has a short circuit.
The **Y Limit** light is never on, even though the switch is actuated.	Remove wire 410 on the machine control board.	
The **Z Limit** light is never on, even though the limit switch is actuated.	Remove wire 411 on the machine control board.	

Note: A defective switch can often be cleaned with compressed air and sprayed with WD-40® to fix a problem.

Note: If the stainless steel limit switch cover doesn't sit tight against the front edge of the mill bed, coolant and chips are allowed to converge on the X-limit switch. Using butyl tape between both prevents this from occurring.

12.8.5 Lost Motion on Axis Travel

The machine uses stepper motors — open-loop control motors that are accurate and reliable — to control axis motion. With stepper motors, however, there's a chance of losing steps in axis motion. This is because lost steps occur when the commanded number of steps and the actual number of steps don't match (a risk with open-loop control). A step mismatch results in a loss of motion on the axis.
In most cases, when a machine loses steps, it loses many steps all at once — resulting in a visible stutter or a stall in axis motion, and/or an audible noise. Lost steps often occur when a stepper motor is pushed too hard or too fast, and it exceeds its limits.
Although this machine uses stepper motors to control axis motion, the entire system is designed to reduce the likelihood of losing steps. In most cases, the machine breaks smaller cutting tools or stalls the spindle with bigger cutting tools before losing steps. Outside variables, like programming, tooling, workholding, and operator error, are sometimes misinterpreted as lost steps.

Cause: Improper use of tool offset, work offset, or cutter compensation.

Probability	How-To Steps	Need More?
High	➢ Examine the G-code programs. You must fully understand tool offsets, work offsets, and cutter compensation.	The most common cause of a perceived loss of position or lost steps is operator error.

Cause: The spindle tooling isn't properly clamped (Z-axis only).

Probability	How-To Steps	Need More?
High	➢ Examine the cutter to verify that it's not slipping in the holder, or that the tool holder isn't pulling out of the spindle collet.	

Cause: The motor coupling is loose or cracked.		
Probability	**How-To Steps**	**Need More?**
Low	➢ Examine the motor coupling.	You may find it useful to carefully run the axis with the cover removed. Make a paint line from the shaft through the coupling to the screw to examine if there's any movement over time.

Cause: The Z-axis brake isn't releasing.		
Probability	**How-To Steps**	**Need More?**
Low	➢ Slowly jog the Z-axis: if the brake isn't releasing, the Z-axis will usually move down properly, but won't move up.	You should be able to hear the motor whenever you command the axis to move. Usually, the brake alone does not have the torque to cause a loss of motion. A condition like poor lubrication in combination with a defective Z brake are required to actually lose position.

Cause: Controller or PathPilot problem.		
Probability	**How-To Steps**	**Need More?**
Low	➢ Restart the controller and send the log file (from the **logfiles** directory) to Tormach Technical Support. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.	For information, see "Getting Help" (page 230).

Cause: There's an obstruction or excessive friction (the gibs aren't adjusted properly, or poor lubrication), or there's high load in the mechanical system.

Probability	How-To Steps	Need More?
Low	➢ Jog the axis and carefully observe the motion.	If you lose steps, it's normally many steps. You should be able to hear the motor. Mechanical issues most often result in losing a large number of steps or stalling. Typical mechanical issues include: an increase in friction due to lack of oil at the way surfaces or ball screw and/or improperly adjusted gibs. They also come from excessive load on the system due to chips or debris on the way surfaces or ball screw, a sticking Z-axis brake or an end-of-travel bumper wedged against the motor mount casting. This occurs sometimes after a limit switch failure and is more common on the Z-axis.

Cause: The axes drivers have the wrong DIP switch settings.

Probability	How-To Steps	Need More?
Low	➢ See the machine's electrical schematic.	New axis drivers require you to set the DIP switches at installation.

12.9 SPINDLE DRIVE SUBSYSTEM

The machine's spindle is driven by an AC motor whose speed is controlled by a variable frequency drive (VFD).
The spindle is in a ready-to-run condition when:

1. The control power is on.
2. The spindle door is closed.
3. The machine is reset.
4. *(If equipped)* The enclosure doors are closed.
5. The spindle brake resistor thermal switch isn't tripped.

To troubleshoot the spindle drive subsystem, read the following:

12.9.1 The Spindle Won't Turn **246**
12.9.2 Machining Operations are Loud ("Chattery") **250**
12.9.3 Can't Load or Unload a Tool, or the Spindle's Drawbar Drags Against the Power Drawbar Cylinder's Piston Bolt **251**

12.9.1 The Spindle Won't Turn

Cause: The motor runs, but the spindle doesn’t turn.		
Probability	**How-To Steps**	**Need More?**
Low	➢ Examine the spindle belt for wear or damage.	If the display on the VFD is on, the belt may be loose or broken. You'll hear the spindle motor running.

Cause: There's no power to the VFD.		
Probability	**How-To Steps**	**Need More?**
—	➢ Examine the VFD display: it has power if its digital lights are on.	When power is removed, the VFD display remains active until the internal capacitors dissipate their energy. That usually takes about five seconds.

Cause: There's no power to the VFD because contactor K2 is not energizing. (Examine the voltage across 112/N and 117 at the VFD, which should be 115 Vac nominal.)

Probability	How-To Steps
High	There are loose power or control wires in the VFD circuit. 1. Power off the machine (see "Power Off the Machine" (page 52)). 2. Examine the circuit for loose wires. 3. Power on the machine (see "Power On the Machine" (page 51)) and test operation.

Probability	How-To Steps
Medium	1. Examine the spindle cover door to verify that it's being held closed. 2. Verify that there's 24 Vdc measured from wire 400 to wire 436.

Probability	How-To Steps
Low	Thermal switch (TS1) tripped, preventing K2 from latching. 1. Power off the machine (see "Power Off the Machine" (page 52)). 2. Allow the brake resistor to cool, and reset thermal switch by pressing reset button (between its two terminals).

Probability	How-To Steps
Low	The control board isn't providing a run command or holding the K2 contactor on. 1. Examine wires 434 and 436 for 24 Vdc on wires J10.1 and J10.3, respectively. 2. Start the spindle and listen for a soft, audible click on the control board. If you hear this click (from a relay contact on the board), the machine control board is functioning properly. If you don't hear the click: • Verify that there's 24 Vdc measured from wire 400 to wire 434. Make a jumper wire and, carefully, momentarily jumper wires 434 and 436. ◦ If contactor K2 pulls in (you will hear an audible clunk) while you have the jumper on but drops out as soon as you remove the jumper, the holding contact on K2 is defective. ◦ If K2 stays powered on, the control board is not passing the run signal to the circuit. The control board passes 24 Vdc from wire 434 to 436 via a relay to create the start pulse. Measure wire 434 for 24 Vdc power. If present, the control board or wire 436 connected to J10.3 is defective. Power off the machine (see "Power Off the Machine" (page 52)), and jumper J10.1 to J10.3 Power on the machine (see "Power On the Machine" (page 51)) and check the VFD for a display. If the VFD reads **rdy**, the control board is defective. If not, wire 436 may be broken. Lift the connections of wire 436 at the control board and K2 and measure continuity.

Cause: The VFD tripped.

Probability	How-To Steps	Need More?
Low	➢ If the VFD tripped, an error code displays. Read the error code and go to "Spindle VFD Trip Reference" (page 249).	You can clear a VFD trip by either: • Removing power from the VFD for 30 seconds. • Pressing the red **Reset** button on the front of the VFD .

Cause: The belt is loose or broken, or sheaves are not fixed to the motor or the spindle.

Probability	How-To Steps
Low	➢ Power off the machine (see "Power Off the Machine" (page 52)). Then, examine the mechanical system.

Cause: The VFD is defective.

Probability	How-To Steps
Low	The VFD may be defective if: • The display isn't on and there is nominal 115 Vac between wires 117 and 112/N at the VFD. • The VFD displays a trip condition that does not clear when power is removed, the VFD may be defective.

Cause: The VFD is not programmed, or it's programmed incorrectly.

Probability	How-To Steps	Need More?
Low	1. Push **Enter** on the front panel of the VFD twice. The display changes to **00.000**, with the **.000** blinking. 2. Repeatedly push the **Up Arrow** until **.000** changes to **.011**. 3. Push **Enter** again. The display shows the model of the machine or accessory (for example, **1100** for an 1100M, or **RT11** for a RapidTurn on an 1100M). 4. Push the **Up Arrow** once more, and the VFD displays parameter **.012**, which is the software version number (for example, version 2.01). 5. Push **Back** to exit this mode.	Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

Cause: The machine control board is defective, or there are defective cables between the machine control board and the spindle VFD.

Probability	How-To Steps
Low	➢ Examine all cables to verify that they're properly seated in their connectors on the machine control board.

Cause: The motor is defective.

Probability	How-To Steps	Need More?
Low	1. Power off the machine (see "Power Off the Machine" (page 52)). 2. Wait 30 seconds, and then remove wires 118, 119, and 120 from the VFD terminals. 3. Measure the resistance between: • Wires 118 and 119 • Wires 119 and 120 • Wires 120 and 118 Resistance should be in the range of approximately 2-4 Ω.	• 0 Ω indicates that the winding is shorted. • >1M Ω indicates that the winding is open. Both cases indicate a defective motor or compromised wiring to the motor from the VFD.

Run and Direction Commands Reference

Command From Card	Monitoring Points One Probe on Each		Voltage Measured	
	Common wire number	Wire number	Voltage when control board command is on	Voltage when control board command is not on
Run (FWD)	403	404	14-20 Vdc	0 Vdc
Reverse	403	406	14-20 Vdc	0 Vdc

The display on the VFD provides valuable information for troubleshooting. The display diagnostics include:

- Frequency output (proportional to speed. Range is ~7 Hz to 142 Hz).
- Status (rd for ready, inh for inhibit which will occur when there is no jumper between terminals B2 and B4 on the drive).
- Fault information (Er for trip) and a code for the fault.

Spindle VFD Trip Reference

Trip Code	Condition	Likely Cause
UU	DC-BUS under-voltage.	This happens when the VFD is powered down.
OU	DC-BUS over-voltage.	Braking resistor failed open or wiring connection open between the VFD and the resistor. Resistance to measure 70 ohms.
OI.AC	VFD output instantaneous over current.	Phase to phase or phase to ground short on output of VFD to motor. This trip code cannot be reset until 10 seconds after the trip was initiated.
OI.br	Braking resistor instantaneous over current.	Braking resistor shorted or partially shorted out or short in wiring between the VFD and the resistor. Resistance to measure 70 ohms. Check brake resistor wiring.
It.br	I^2t (power) on braking resistor.	Excessive braking resistor energy caused by too frequent and too severe deceleration cycles or AC supply voltage too high.
It.AC	I^2t (power) on VFD output current (used to protect motor).	You are working the spindle motor too hard. Ensure that the spindle is not jammed or sticking. Consider running the spindle motor at half speed for 10 minutes with no load to cool the motor down.
Oht.C	VFD is working too hard and stops to cool power electronics down to prevent failure.	Spindle motor working too hard. Stop running the spindle but leave the VFD power on and let the power electronics cool down.
Oht.I	Heat sink temperature is too high because the VFD is working too hard and stops to cool power electronics down to prevent failure. Cabinet may also be too hot.	Spindle motor working too hard or it is too hot in work location. Stop running the spindle but leave the VFD power on and let the power electronics cool down. Check to see if the fan on the VFD is running and check filters on the cabinet. Cool work location down if required.
HF01 through HF23	Cooling fan is not cooling.	Failed drive.

12.9.2 Machining Operations are Loud ("Chattery")

Cause: Inappropriate cutting parameters or CAM settings.	
Probability	**How-To Steps**
High	1. Verify that you're using the correct cutting parameters: use the feed rate and spindle overrides to adjust cutting parameters during operation. 2. Confirm that tool offsets are correct.

Cause: Worn or broken cutting tools.	
Probability	**How-To Steps**
High	➢ Inspect for worn or broken cutting tools, and replace as necessary.

Cause: Swarf in the spindle or on the tool holder's shank.	
Probability	**How-To Steps**
Medium	1. Inspect inside the spindle and on the tool holder's shank for swarf. If necessary, clean the components. 2. Verify that the spindle and tool holder's contact surfaces are clean, dry, and free of grease or oil.

Cause: Insufficient preload of drawbar springs.	
Probability	**How-To Steps**
Medium	Verify that there's sufficient preload of the drawbar disc springs: 1. Examine the shop air pressure, and verify that there's a minimum of 90 psi compressed air at the machine's FRL Filter-Regulator-Lubricator. If the machine's inlet air pressure is too low, it limits the machine's maximum tool clamping force. 2. Verify that the clamping force is increased as high as possible while still smoothly and reliably clamping and unclamping tool holders.

Cause: Cracked or broken disc springs.	
Probability	**How-To Steps**
Low	➢ Remove the disc springs from the drawbar assembly and inspect them for damage. If you find any cracked or fractured springs, replace all eight disc springs in the stack with Power Drawbar Spring Washer (PN 31319).

12.9.3 Can't Load or Unload a Tool, or the Spindle's Drawbar Drags Against the Power Drawbar Cylinder's Piston Bolt

Cause: Insufficient shop air pressure.	
Probability	**How-To Steps**
High	➢ Examine the shop air pressure, and verify that there's a minimum of 90 psi compressed air at the machine's FRL Filter-Regulator-Lubricator.

Cause: Power drawbar cylinder piston is out of adjustment range. (For three-stack power drawbar cylinders only.)	
Probability	**How-To Steps**
Low	1. Loosen the power drawbar cylinder's jam nut and adjust the piston bolt. Verify that the piston bolt sits within 0.5 mm (0.020 in.) of the spindle's spring stack when there's no tool loaded in the spindle. 2. Secure the jam nut.

Cause: The pull stud clamp has loosened from the end of the spindle's drawbar shaft.	
Probability	**How-To Steps**
Very Low	1. Use the BT30 Clamping Unit Installation Tool (PN 50385) that was provided either with your machine or with your upgrade kit to verify that the clamping unit is securely tightened onto the drawbar shaft. If the clamping unit is loose: a. Uninstall the clamping unit and inspect it for wear or damage. If you find any damage, replace it with Clamping Unit, BT30 (PN 39690). b. Reinstall the clamping unit: apply medium-strength (blue) thread-locking compound to the threads, and tighten the clamping unit onto the drawbar shaft with the installation tool.

12.10 OPERATOR CONSOLE TROUBLESHOOTING

12.10.1 The Screen Doesn't Respond to Touch Inputs **252**
12.10.2 The Screen Doesn't Display an Image or Respond to Power Button **253**
12.10.3 The Screen is Scrambled or Illegible **253**
12.10.4 The Knobs Don't Respond **254**
12.10.5 The Buttons Don't Respond **255**

12.10.1 The Screen Doesn't Respond to Touch Inputs

Problem

The touch screen does not respond to touch inputs on all or part of the screen's surface.

Cause

The sensitivity setting for the touch controller is too low.

Solutions

You Might Need To...	Probability	How-To Steps	Need More?
Adjust touchscreen sensitivity.	High	1. Verify that you have PathPilot **v2.4.4** or higher installed on your controller. 2. From the PathPilot interface, in the **MDI Line** DRO field, type `ADMIN TOUCHSCREEN SENSITIVITY 1000` and press **Enter**. You can use a value between 1 and 2047, but 1000 is generally sufficient for most shop spaces. 3. Verify that the touch screen responds to touch inputs. If it doesn't, go to the next step. 4. From the PathPilot interface, on the **File** tab, find the **pointercal.xinput** file and delete it. 5. Restart the PathPilot controller. The calibration utility displays. For now, skip this procedure. 6. From the PathPilot interface, in the **MDI Line** DRO field, type `ADMIN TOUCHSCREEN SENSITIVITY 1000` and press **Enter**. 7. From the PathPilot interface, in the **MDI Line** DRO field, type `ADMIN TOUCHSCREEN` and press **Enter**. The calibration utility displays. Use your finger (not a mouse) to touch all four points that display on the screen.	The touchscreen is a resistive type to prevent accidental triggering from drops of coolant on the screen. The resistive touchscreen may need its sensitivity adjusted when used in a shop space with very high or low humidity.

12.10.2 The Screen Doesn't Display an Image or Respond to Power Button

Problem

The console screen doesn't display an image or respond to the power button.

Cause

The console isn't receiving power.

Solutions

You Might Need To...	Probability	How-To Steps	Need More?
Examine power input to the console.	High	➢ Examine the green LED on the power brick for the console. If it's not lit, examine the power cords to the power brick.	If your console receives power from the Accessory Input ports on the machine, look for tripped breakers inside your machine's electrical cabinet.
Test the power button functionality.	Low	➢ Examine the green ring around the power button. It should light up when you press the power button.	

12.10.3 The Screen is Scrambled or Illegible

Problem

The console screen turns on, but is scrambled or illegible.

Cause

The BIOS isn't configured for the correct screen output.

Solutions

You Might Need To...	Probability	How-To Steps	Need More?
Configure the display output settings in BIOS.	High	1. Connect a VGA monitor to the console. 2. Power the console on and select the **Delete** key to enter the BIOS. 3. From the **Advanced** tab, select **Display Configuration**. 4. Configure the display as follows: • Primary IGFX Boot Display: **Auto** • LCD Panel Type: **1280x1024 LVDS** • Panel Channel: **Dual Channel** • Panel Color Depth: **24 Bit** 5. Select the **Esc** key, go to **Save and Exit**, and select **Save Changes and Reset**.	This configuration problem can occur if your console has a CMOS battery failure. Replace the battery if it reoccurs.

12.10.4 The Knobs Don't Respond

Problem

The RPM, Feed Override, or Max Velocity knobs don't respond or aren't smooth.

Cause

The ribbon cable connecting the knobs is disconnected or the circuit board is damaged.

Solutions

You Might Need To...	Probability	How-To Steps	Need More?
Examine the connectors on the ribbon cable.	High	1. Remove the rear panel of the console. 2. Examine the connectors on both ends of the cable going from J4 on the control board to the potentiometer board.	Shipping can sometime cause connectors to become loose. Re-seating the connectors will usually fix non-responsive override knobs.

You Might Need To...	Probability	How-To Steps	Need More?
Examine the USB connection to the control board.	High	1. Remove the rear panel of the console. 2. Examine the USB cable going from the header on the computer motherboard to connector J12 on the control board.	Verify that the power LED on the console control board lights up when the console is turned on. If it doesn't light up, and you have confirmed the USB connection, replace the control board (PN 39146).

12.10.5 The Buttons Don't Respond

Problem

The Cycle Start or Feed Hold buttons don't respond.

Cause

The control board is disconnected or the wires to the buttons are loose.

Solutions

You Might Need To...	Probability	How-To Steps	Need More?
Examine the wiring to the buttons.	High	1. Remove the rear panel of the console. 2. Examine the wire inputs to connector J13 on the control board. If any wires are loose, tighten the screw terminals. 3. Using a continuity tester, measure the resistance between terminals 1 and 2 when Feed Hold is pressed and 3 and 4 when Cycle Start is pressed. • If there's continuity at the terminals on the control board and the buttons still don't work, examine the USB cable to the control board. • If there's not continuity at the terminals when the buttons are pressed, remove the lower rear panel of the console and examine the screw terminals on the rear of the buttons themselves.	Shipping can sometime cause wire terminals to become loose. Re-seating the wires will usually fix non-responsive buttons. If you have tested all terminals and the buttons still don't have continuity when pressed, replace the buttons: • Feed Hold Button (PN 37363) • Cycle Start Button (PN 37362)
Examine the USB connection to the control board.	High	1. Remove the rear panel of the console. 2. Examine the USB cable going from the header on the computer motherboard to connector J12 on the control board.	Verify that the power LED on the console control board lights up when the console is turned on. If it doesn't light up and you have confirmed the USB connection, replace the control board (PN 39146).

DRMACH

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.

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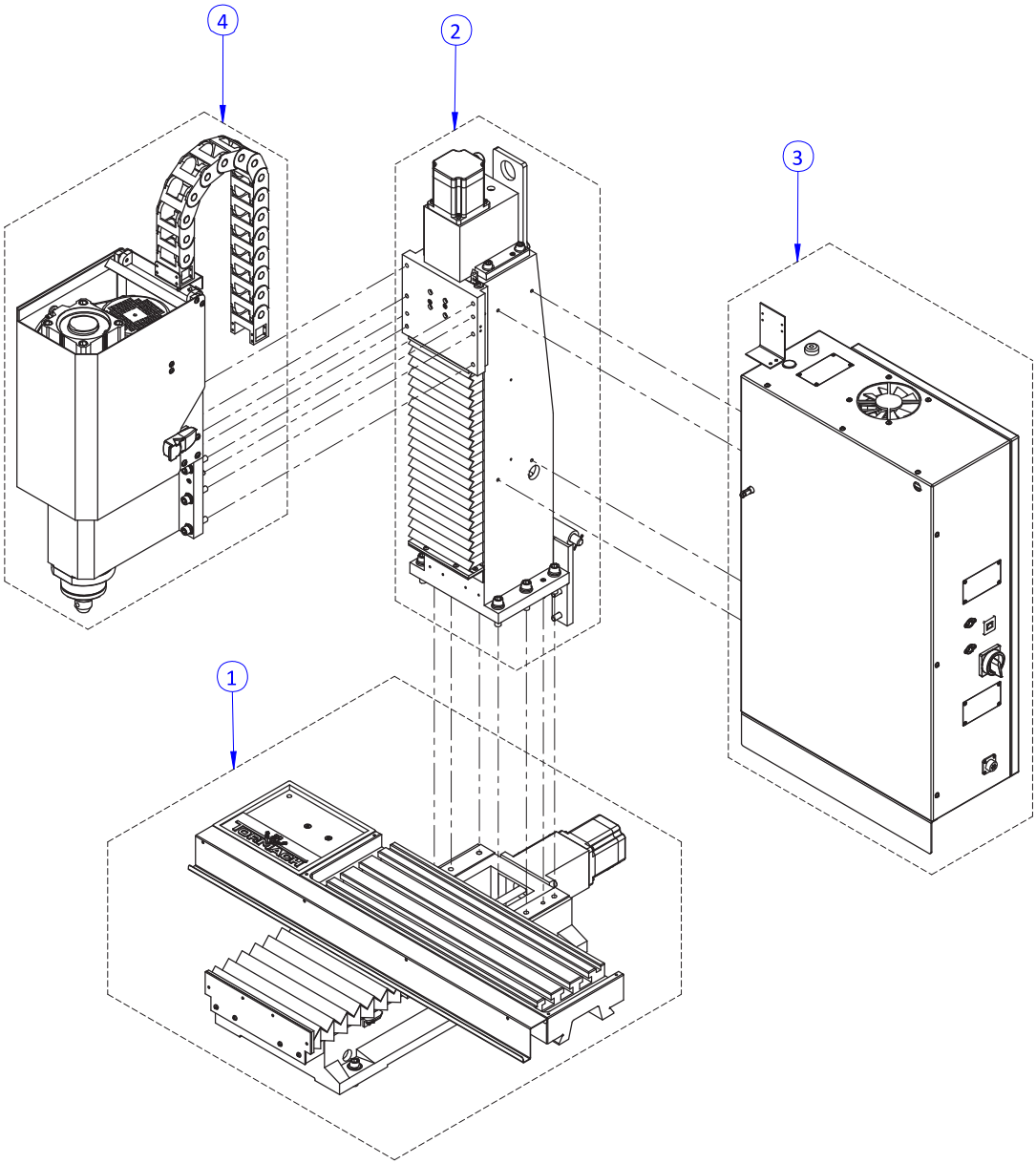
13: DIAGRAMS AND PARTS LISTS

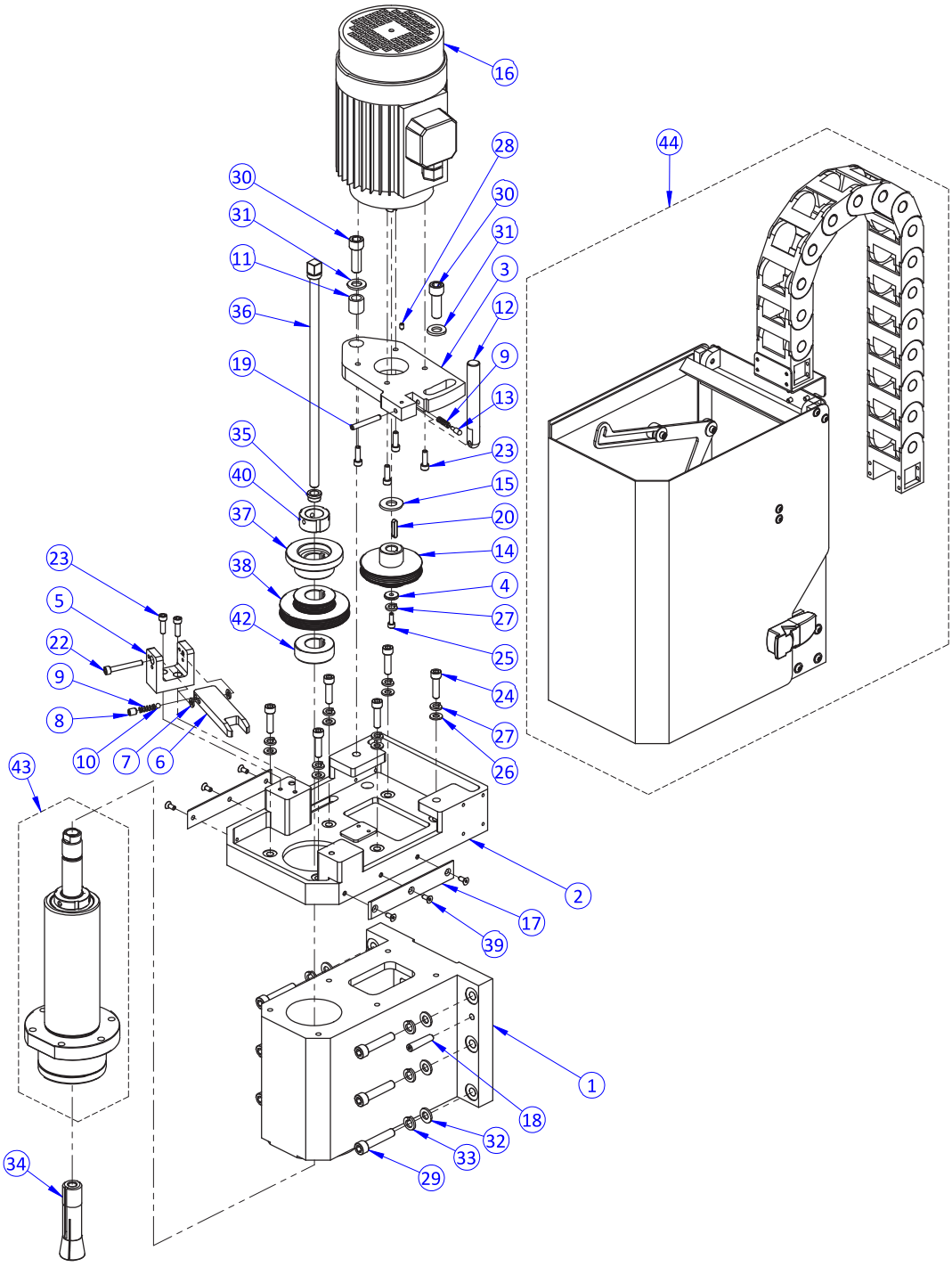
13.1 BASE MACHINE EXPLODED VIEW



13.2 BASE MACHINE PARTS LIST

ID	Description	Quantity
1	"X-Y Axis Assembly Exploded View" (page 277)	1
2	"Z-Axis Assembly Exploded View" (page 279)	1
3	Electrical Cabinet	1
	Fan Guard Filter, 120 mm (PN 37948)	1
	Fan Guard, 120 mm (PN 37947)	1
4	"Spindle Head Exploded View" (on the next page)	1

13.3 SPINDLE HEAD EXPLODED VIEW



13.4 SPINDLE HEAD PARTS LIST

ID	Description	Quantity
1	770 Head Casting (PN 31522)	1
2	770 Spindle Motor Base (PN 31548)	1
3	770 Motor Mount Plate (PN 31549)	1
4	Tightening Washer (PN 31536)	1
5	Spindle Lock Base (PN 38716)	1
6	770M Spindle Lock Bar (PN 38718)	1
7	Washer, M6, Nylon (PN 38714)	2
8	Screw, M8 × 1.25 - 10 mm (PN 31682)	1
9	Spring, 6 mm × 20 mm (PN 31559)	2
10	Ball, 6 mm, Steel (PN 38225)	1
11	Pivot Bushing (PN 31555)	1
12	Adjustable Base Handle (PN 31556)	1
13	Pin (PN 31558)	1
14	Motor Pulley, 770 (PN 31571)	1
15	Motor Pulley Spacer, 770 (PN 31595)	1
16	Spindle Motor, 770 (PN 31431)	1
17	Wear Strip, Spindle Door (PN 38451)	2
18	Tapered Dowel Pin, 8 × 40 mm (PN 31544)	2
19	Pin, Pull-out, 6 × 45, M4 × 0.7 Thread (PN 31557)	1
20	Square Key, 5 × 20 (PN 31535)	1
21	Power Drawbar Spring Washer (PN 31319)	7
22	Screw, Socket Head Cap, M6 × 1 - 45 (PN 38715)	1
23	Screw, Socket Head Cap, M6 × 1 - 20 (PN 30832)	6
24	Screw, Socket Head Cap, M8 × 1.25 - 30 (PN 30544)	6
25	Screw, Socket Head Cap, M5 × 0.8 - 14 (PN 31563)	1
26	Washer, Flat, M8 (PN 30531)	6
27	Washer, Split Lock, M8 (PN 32339)	7
28	Screw, Cone Point Set, M5 x 0.8 - 8 (PN 30337)	1
29	Screw, Socket Head Cap, M10 × 1.5 × 50 (PN 31597)	6
30	Screw, Socket Head Cap, M12 × 1.75 × 35 (PN 35762)	2
31	Washer, Flat, M12 (PN 32473)	2

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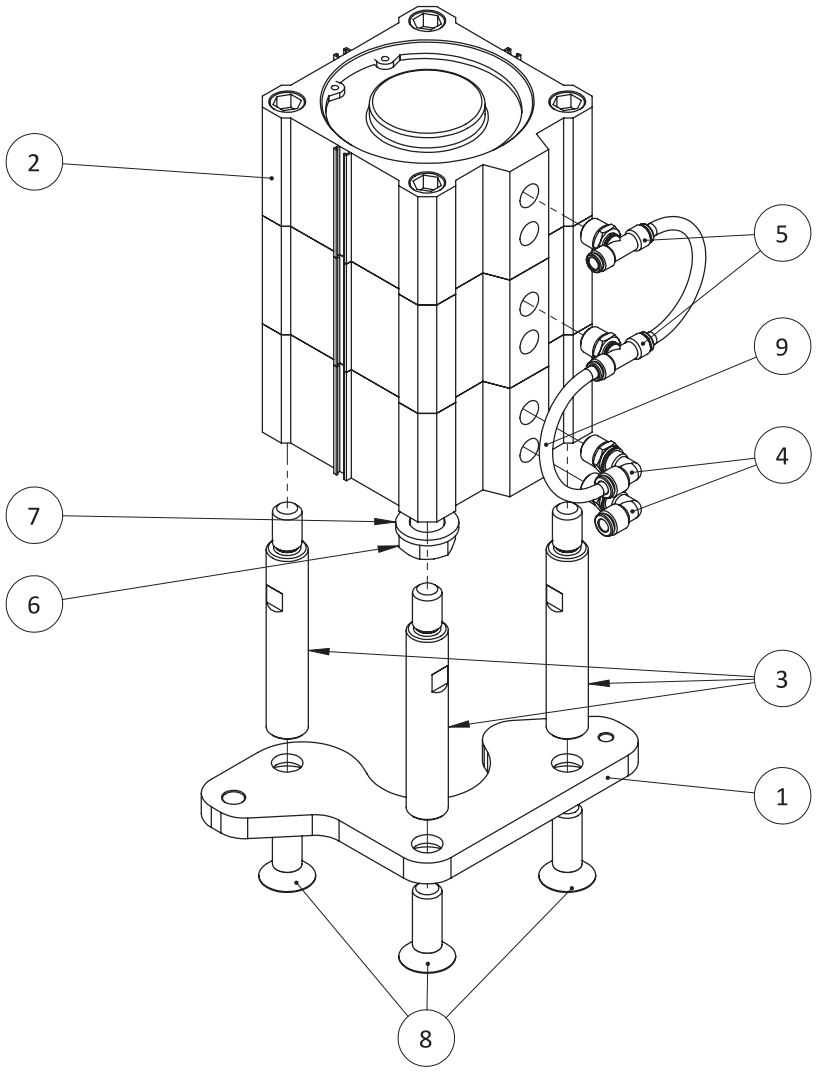
ID	Description	Quantity
32	Washer, Flat, M10 (PN 30919)	6
33	Washer, Split Lock, M10 (PN 31684)	6
34	Tormach Tooling System (TTS) Adapter Collet: R8 (PN 50568)	1
35	Power Drawbar Alignment Bushing (PN 31330)	1
36	Drawbar, R8 (7/16-20), 305 mm (PN 38793)	1
37	Power Drawbar Flange[1]	1
38	Spindle Pulley[1]	1
39	Screw, Flat Head Cap, M5 × 0.8 - 12 (PN 38894)	6
40	Bearing Nut, M25 × 1.5, Set Screw (Angled)[1]	1
42	Spindle Pulley Spacer[1]	1
43	R8-TTS Spindle Assembly, 770M (PN 37960)[1]	1
44	"Spindle Motor Cover Exploded View" (page 267)	1

[1]R8-TTS Spindle Assembly, 770M (PN 37960) includes the following balanced and matched parts: #37, #38, #40, #42, and #43.

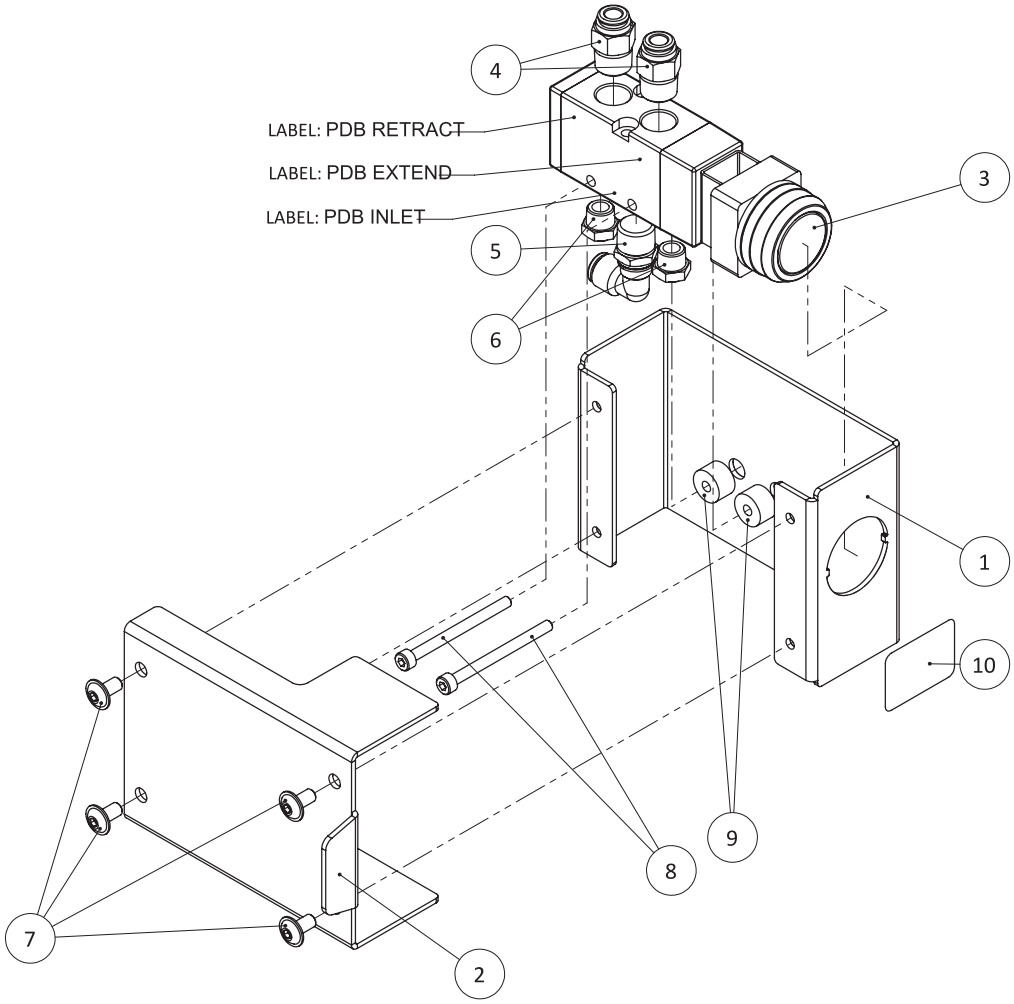
13.5 TTS POWER DRAWBAR CYLINDER EXPLODED VIEW



13.6 TTS POWER DRAWBAR CYLINDER ASSEMBLY PARTS LIST

ID	Description	Quantity
1	Power Drawbar Mount Plate (PN 37747)	1
2	Pneumatic Cylinder, Double Acting, 100 mm Bore, 12 mm Stroke, 3-Stack (PN 31313)	1
3	Power Drawbar Standoff, M14 × 2 (PN 38282)	3
4	Fitting, Elbow, 1/4 NPT to 1/4 in. PTC (Male) (PN 31324)	2
5	Fitting, Branch Tee, 1/4 NPT to 1/4 OD Tube (PN 31325)	2
6	Screw, Hex Head Cap, M16 × 1.5 - 25 (PN 31322)	1
7	Washer, Flat, M16 (PN 31445)	1
8	Screw, Flat-Head Cap, M14 × 2 - 40 (PN 38285)	3
9	Tube, 1/4 in. OD, Plastic (Red) - 125 mm (PN 38408)	2

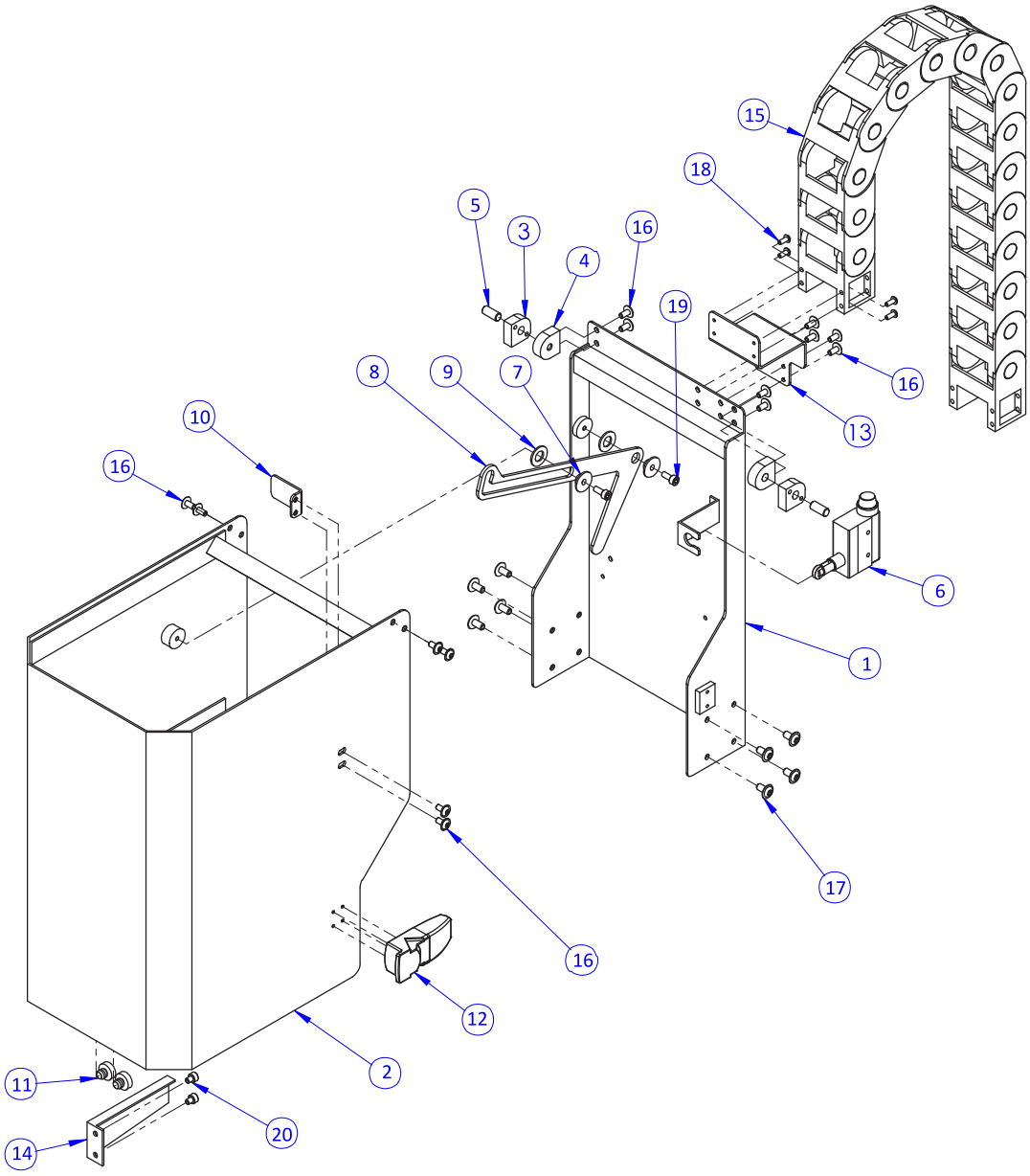
13.7 POWER DRAWBAR PUSH BUTTON EXPLODED VIEW



13.8 POWER DRAWBAR PUSH BUTTON PARTS LIST

ID	Description	Quantity
1	Power Drawbar Push Button Base (PN 38217)	1
2	Power Drawbar Push Button Cover (PN 38218)	1
3	Push Button Air Valve (4-Way, 5-Port) (PN 37295)	1
4	Fitting, Male Connector, 1/4 NPT to 1/4 in. PTC (PN 32212)	2
5	Fitting, Elbow, 1/4 NPT to 1/4 in. PTC (Male) (PN 31324)	1
6	Fitting, Muffler (Flat), 1/8 NPT (PN 37297)	2
7	Screw, Button Head Cap (Flanged), M5 × 0.8 - 10, Stainless Steel (PN 38205)	4
8	Screw, Socket Head Cap, M4 × 0.7 - 50 (PN 38220)	2
9	Power Drawbar Push Button Spacer (PN 38219)	2
10	Decal, Power Drawbar, Release Tool (PN 37340)	1

13.9 SPINDLE MOTOR COVER EXPLODED VIEW



13.10 SPINDLE MOTOR COVER PARTS LIST

ID	Description	Quantity
1	770 Rear Spindle Cover (PN 37699)	1
2	770 Front Spindle Cover (PN 37700)	1
3	Cover Hinge (PN 37693)	2
4	Cover Pivot (PN 37694)	2
5	Cover Axel (PN 37696)	2
6	Spindle Door Switch (PN 30461)	1
7	Lid Support Bushing (PN 38447)	2
8	Spindle Motor Cover Lid Support (PN 38446)	1
9	Lid Support Washer (PN 38448)	2
10	Cover Dog (PN 37695)	1
11	Bumper, Push-In, 16 mm × 8.5 mm, Rubber (PN 38450)	2
12	Spindle Motor Cover Latch (PN 31199)	1
13	770 Upper Drag Chain Mount (PN 38454)	1
14	Spindle Door Latch Guard (PN 38878)	1
15	770M Drag Chain (PN 38465)	1
16	Screw, Button Head Cap (Flanged), M5 × 0.8 - 10, Stainless Steel (PN 38205)	14
17	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	8
18	Screw, Button Head Cap, M4 × 0.7 - 10 mm (PN 38904)	4
19	Screw, Socket Head Cap, M5 × 0.8 - 12 mm (PN 31353)	2
20	Screw, Socket Head Cap, M5 × 0.8 - 6 (PN 38905)	2

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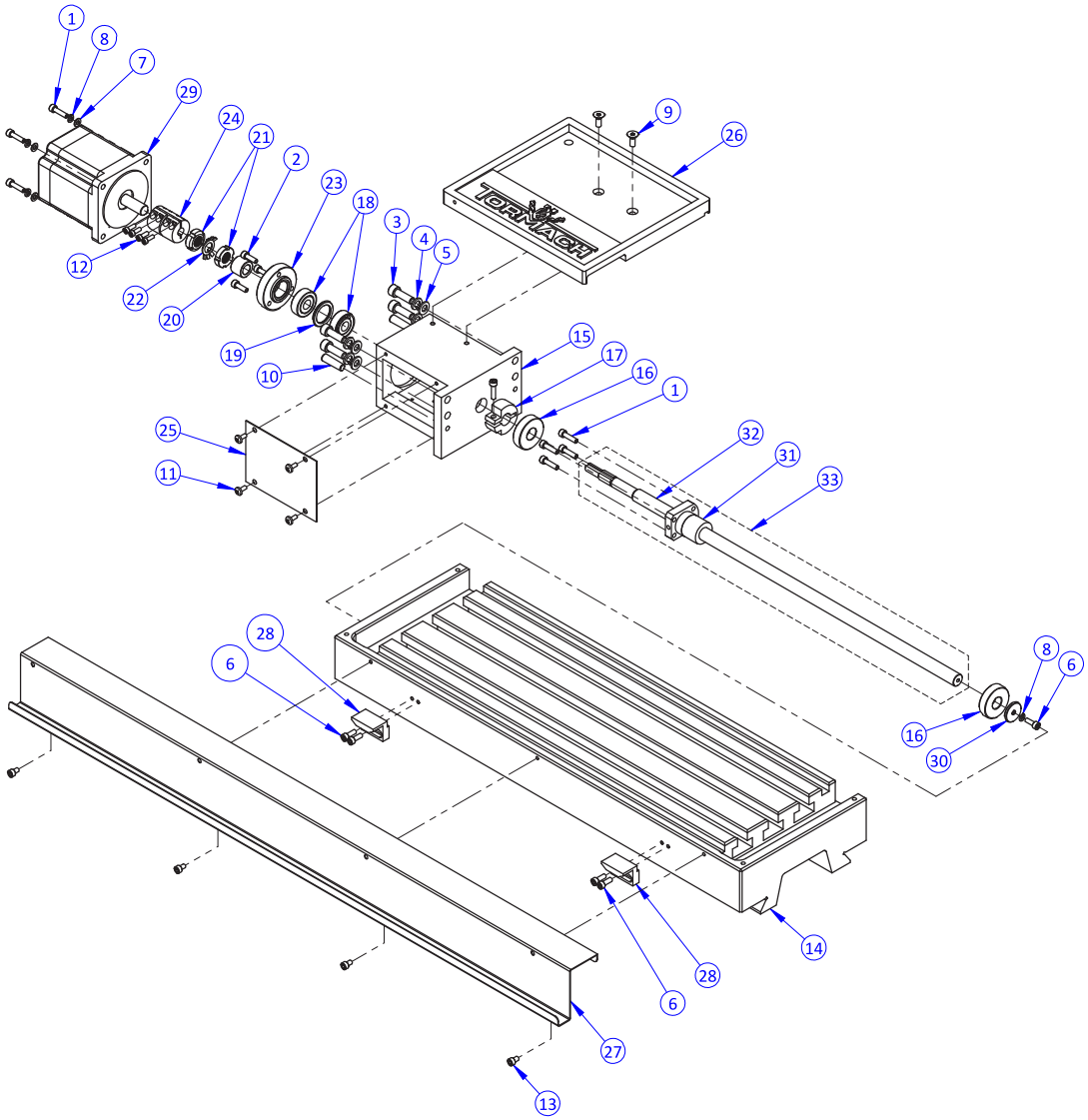
13.11 X-AXIS ASSEMBLY EXPLODED VIEW



13.12 X-AXIS ASSEMBLY PARTS LIST

ID	Description	Quantity
1	Screw, Socket Head Cap, M5 × 0.8 - 20 (PN 30357)	9
2	Screw, Socket Head Cap, M5 × 0.8 - 16 (PN 30546)	3
3	Screw, Socket Head Cap, M8 × 1.25 - 25 (PN 31618)	4
4	Washer, Split Lock, M8 (PN 32339)	4
5	Washer, Flat, M8 (PN 30531)	4
6	Screw, Socket Head Cap, M5 × 0.8 - 14 (PN 31563)	5
7	Washer, Flat, M5 (PN 39305)	4
8	Washer, Split Lock, M5 (PN 31572)	5
9	Screw, Flat Head Cap, M6 × 1 - 16 (PN 31633)	2
10	Pin, Taper, 8 × 30, M5 Thread (PN 31620)	2
11	Screw, Pan Head Machine, M5 × 0.8 - 10 (PN 30417)	4
12	Screw, Socket Head Cap, M4 × 0.7 - 12 (PN 31360)	4
13	Screw, Socket Head Cap, M5 × 0.8 - 8 (PN 30844)	4
14	770 Machine Table (PN 31625)	1
15	770 X-Axis Motor Mount (PN 31626)	1
16	X/Y-Axis Ball Screw End Bumper, 770 (PN 31613)	2
17	770 Ball Screw End Stop Clamp (PN 31614)	1
18	X-/Y-Axis Ball Screw Support Bearing (PN 31432)	2
19	770 X-Y Ball Screw Bearing Spacer (PN 31615)	1
20	Sleeve (PN 31537)	1
21	770 X and Y Ball Screw Preload Nut (PN 31616)	2
22	770 Tab Washer for Preload Nut (PN 31542)	1
23	Bearing Cap (PN 31530)	1
24	Ball Screw Coupler (PN 31421)	1
25	770 X-Y Motor Mount Cover Plate (PN 31621)	1
26	Tool Tray, 770 (PN 38868)	1
27	Table Drip Guard, 770 (PN 31420)	1
28	X-Axis Limit Switch Flag (PN 31208)	2
29	X-Axis Motor, 770M (PN 39413)	1
30	Washer, Flat, 5 × 25, 3 mm Thick (PN 31532)	1

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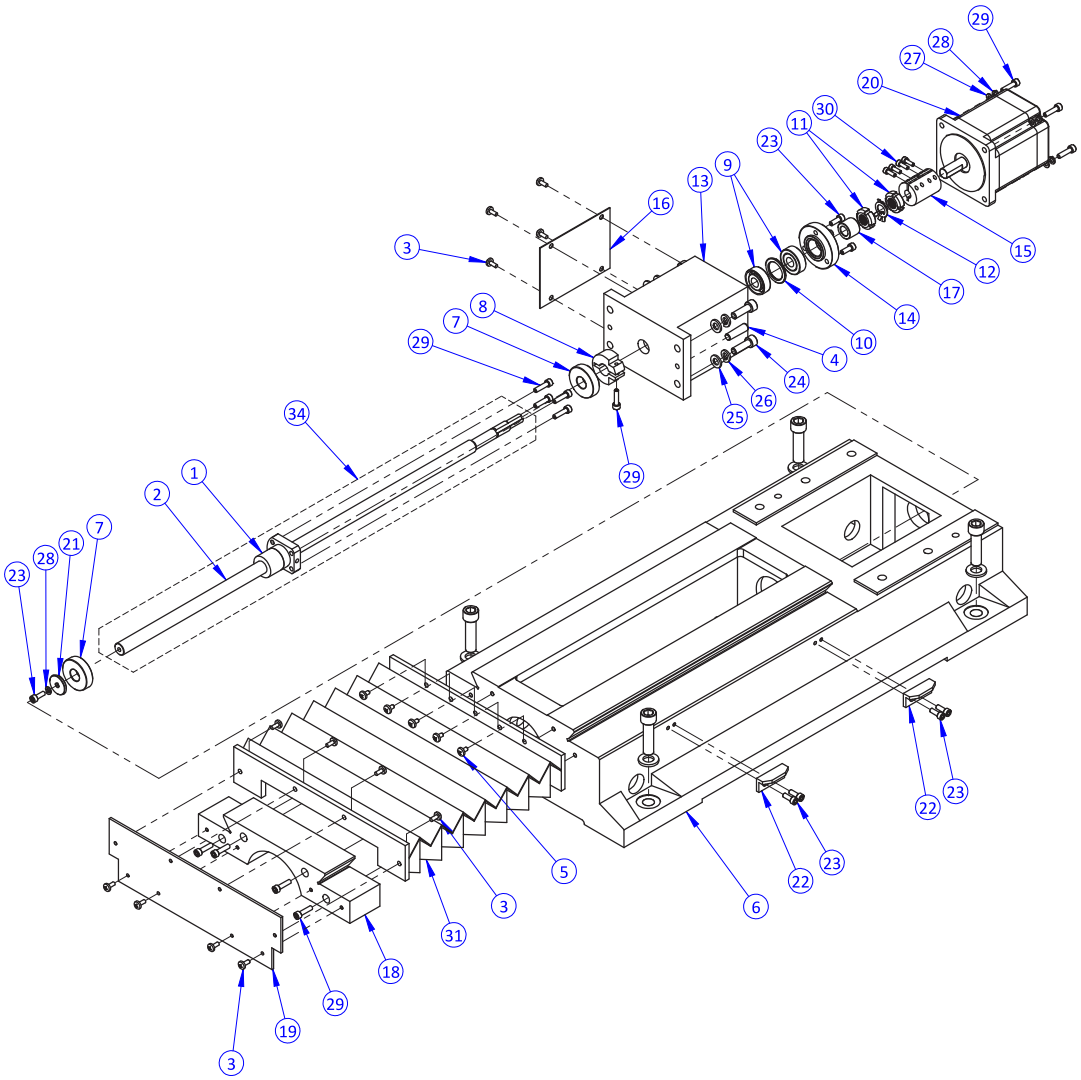
ID	Description	Quantity
31	770 X-Y Ball Nut (PN 38871)	1
32	770 X-Axis Ball Screw (PN 38869)	1

13.13 Y-AXIS ASSEMBLY EXPLODED VIEW



13.14 Y-AXIS ASSEMBLY PARTS LIST

ID	Description	Quantity
1	770 X-Y Ball Nut (PN 38871)	1
2	770 Y-Axis Ball Screw (PN 38870)	1
3	Screw, Pan Head Machine, M5 × 0.8 - 10 (PN 30417)	12
4	Pin, Taper, 8 × 30, M5 Thread (PN 31620)	2
5	Screw, Pan Head Machine, M5 × 0.8 - 8 (PN 31599)	5
6	770 Machine Base (PN 31606)	1
7	X/Y-Axis Ball Screw End Bumper, 770 (PN 31613)	2
8	770 Ball Screw End Stop Clamp (PN 31614)	1
9	X-/Y-Axis Ball Screw Support Bearing (PN 31432)	2
10	770 X-Y Ball Screw Bearing Spacer (PN 31615)	1
11	770 X and Y Ball Screw Preload Nut (PN 31616)	2
12	770 Tab Washer for Preload Nut (PN 31542)	1
13	770 Y-Axis Motor Mount (PN 31617)	1
14	Bearing Cap (PN 31530)	1
15	Ball Screw Coupler (PN 31421)	1
16	770 X-Y Motor Mount Cover Plate (PN 31621)	1
17	Sleeve (PN 31537)	1
18	770 Y-Axis Bellows Holder (PN 31627)	1
19	Y Cover Mounting Plate (PN 31628)	1
20	Y-Axis Motor, 770M (PN 39414)	1
21	Washer, Flat, 5 × 25, 3 mm Thick (PN 31532)	1
22	Y-Axis Limit Switch Flag (PN 30450)	2
23	Screw, Socket Head Cap, M5 × 0.8 - 14 (PN 31563)	8
24	Screw, Socket Head Cap, M8 × 1.25 - 25 (PN 31618)	4
25	Washer, Flat, M8 (PN 30531)	4
26	Washer, Split Lock, M8 (PN 32339)	4
27	Washer, Flat, M5 (PN 39305)	4
28	Washer, Split Lock, M5 (PN 31572)	5
29	Screw, Socket Head Cap, M5 × 0.8 - 20 (PN 30357)	13
30	Screw, Socket Head Cap, M4 × 0.7 - 12 (PN 31360)	4
31	Y-axis Front Way Cover, 770 (PN 31419)	1

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ID	Description	Quantity
32	Screw, Socket Head Cap, M12 × 1.75 - 45 (PN 30349)	4
33	Washer, Flat, M12 (PN 32473)	4
34	Y-Axis Ball Screw Assembly, 770 (PN 31425)	1

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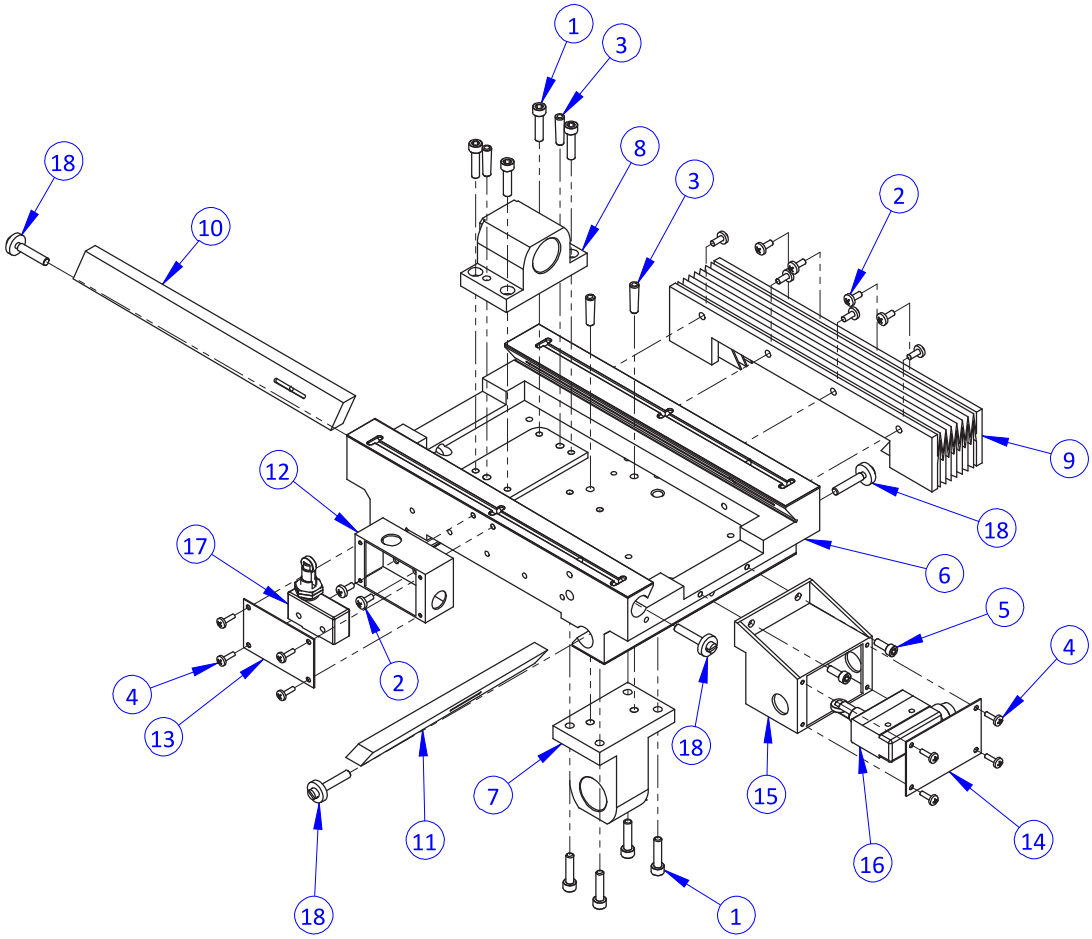
13.15 Y-AXIS SADDLE EXPLODED VIEW



13.16 Y-AXIS SADDLE PARTS LIST

ID	Description	Quantity
1	Screw, Socket Head Cap, M6 × 1 - 25 (PN 31685)	8
2	Screw, Pan Head Machine, M5 × 0.8 - 10 (PN 30417)	10
3	6 - 25 Taper Pin (PN 30439)	4
4	Screw, Pan Head Machine, M4 × 0.7 - 12 (PN 30403)	8
5	Screw, Socket Head Cap, M5 × 0.8 - 14 (PN 31563)	2
6	770 Y-Axis Saddle (PN 31607)	1
7	Y Ball Nut Carrier (PN 31608)	1
8	X Ball Nut Carrier (PN 31624)	1
9	Y-axis Rear Way Cover, 770 (PN 31437)	1
10	770 X-Axis Gib (PN 31631)	1
11	770 Y-Axis Gib (PN 31632)	1
12	X-Axis Limit Switch Box (PN 31634)	1
13	X-Axis Limit Switch Box Cap (PN 31635)	1
14	Y-Axis Limit Switch Box Cap (PN 31640)	1
15	Y-Axis Limit Switch Box (PN 31638)	1
16	Y-Axis Limit Switch (PN 30461)	1
17	X-/Z-Axis Limit Switch (PN 31860)	1
18	Adjustment Screw (PN 31525)	4

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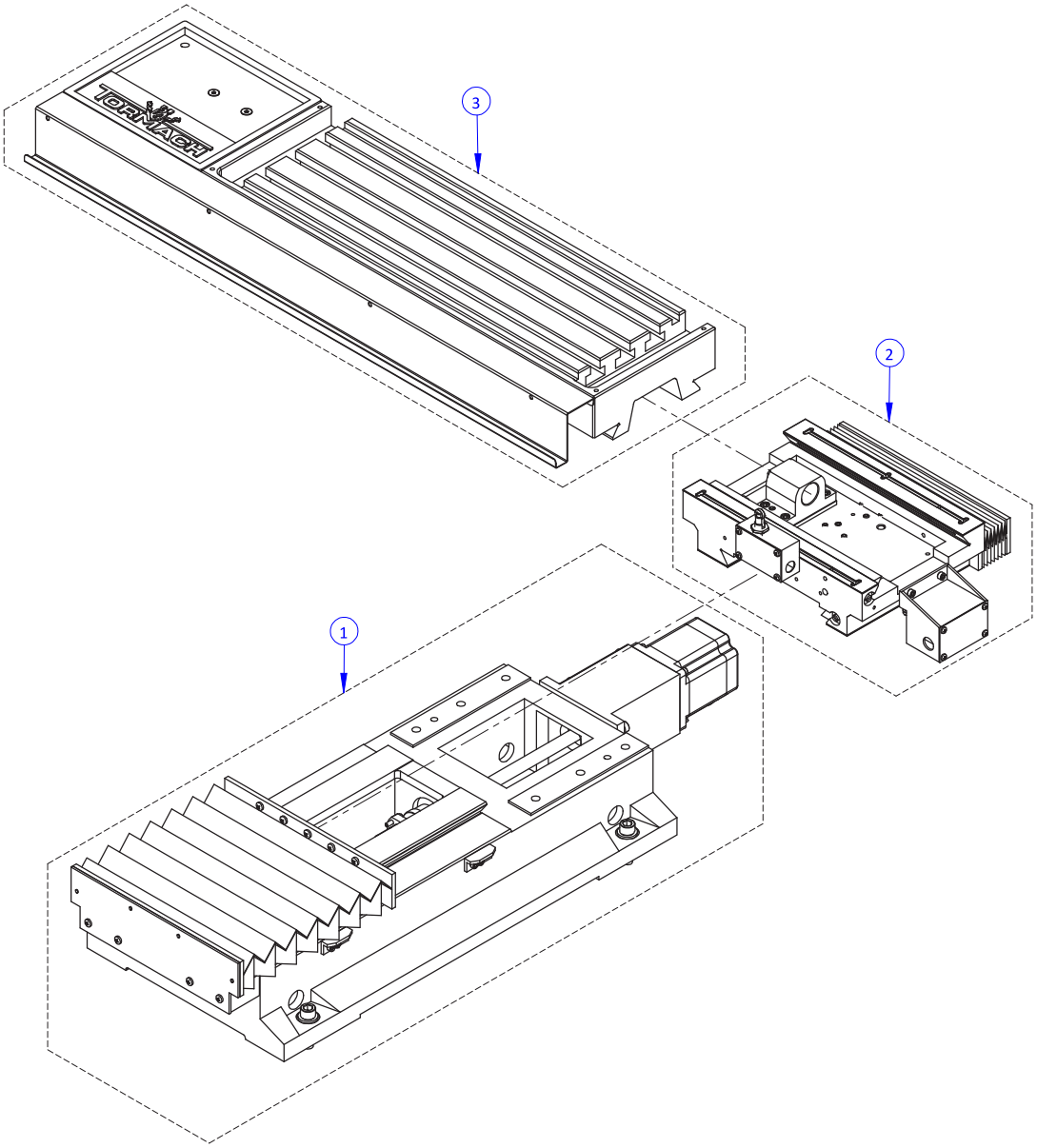
13.17 X-Y AXIS ASSEMBLY EXPLODED VIEW



13.18 X-Y AXIS ASSEMBLY PARTS LIST

ID	Description	Quantity
1	"Y-Axis Assembly Exploded View" (page 272)	1
2	"Y-Axis Saddle Exploded View" (page 275)	1
3	"X-Axis Assembly Exploded View" (page 269)	1

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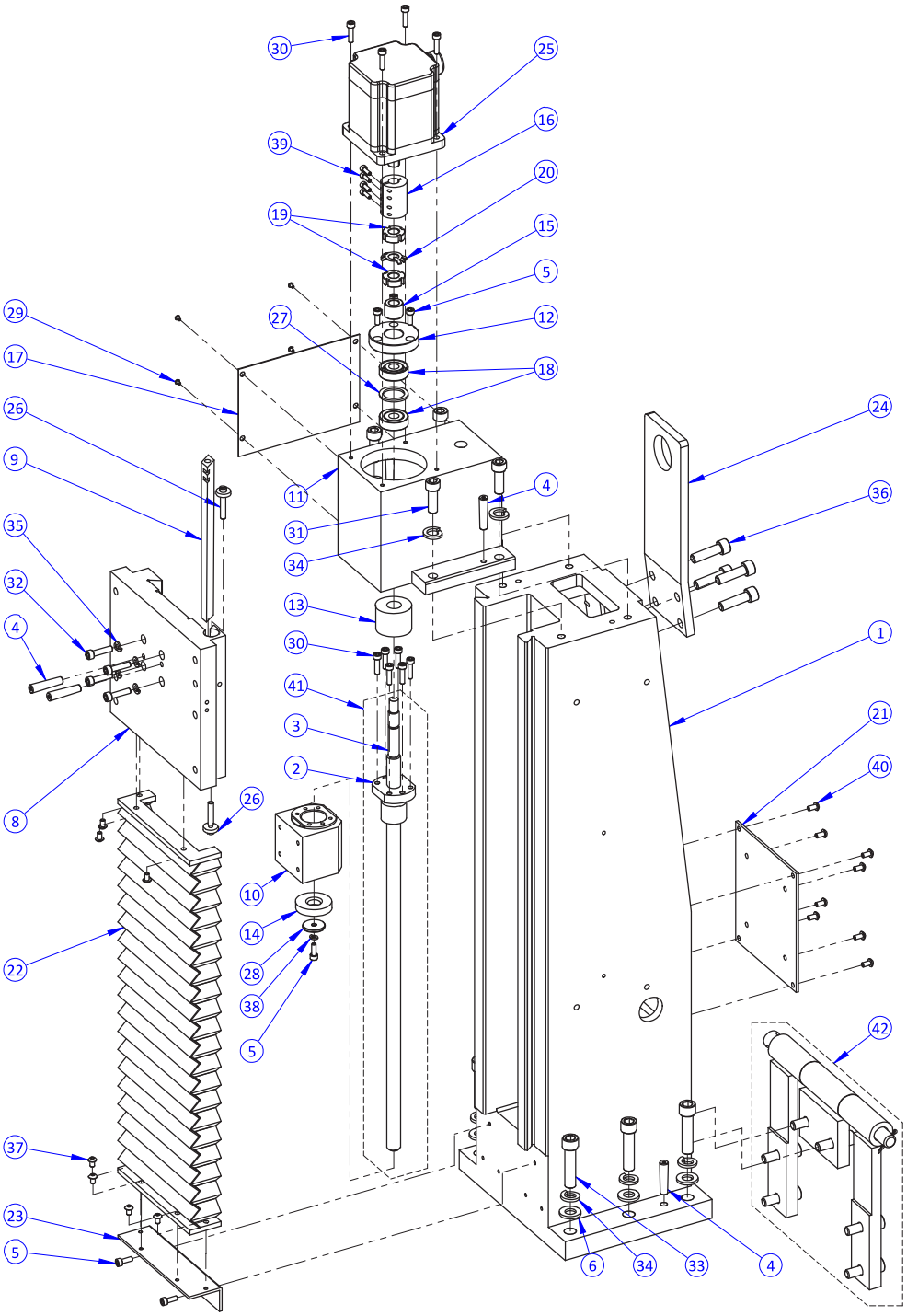
13.19 Z-AXIS ASSEMBLY EXPLODED VIEW



13.20 Z-AXIS ASSEMBLY PARTS LIST

ID	Description	Quantity
1	770 Column (PN 31521)	1
2	770 Z-Axis Ball Nut (PN 38862)	1
3	770 Z-Axis Ball Screw (PN 38863)	1
4	Tapered Dowel Pin, 8 × 40 mm (PN 31544)	6
5	Screw, Socket Head Cap, M5 × 0.8 - 14 (PN 31563)	6
6	Washer, Flat, M12 (PN 32473)	6
7	Washer, Flat, M10 (PN 30919)	6
8	Z-Axis Slide (PN 31523)	1
9	Z-Axis Gib (PN 31524)	1
10	770 Z Ball Nut Carrier (PN 38864)	1
11	Z-Axis Motor Base (PN 31528)	1
12	Bearing Cap (PN 31530)	1
13	Z-Axis Ball Screw Upper Bumper, 770 (PN 31531)	1
14	Z-Axis Ballscrew Lower Bumper, 770 (PN 31533)	1
15	Sleeve (PN 31537)	1
16	Ball Screw Coupler (PN 31421)	1
17	Side Mounting Plate (PN 31538)	1
18	X-/Y-Axis Ball Screw Support Bearing (PN 31432)	2
19	Z-Axis Ball Screw Preload Nut for 770 (PN 31541)	2
20	770 Tab Washer for Preload Nut (PN 31542)	1
21	Column Cover Plate (PN 31583)	1
22	Z-axis Way Cover (PN 31433)	1
23	Lower Bellows Mounting Plate (PN 31584)	1
24	770 Lifting Bracket (PN 31591)	1
25	Z-Axis Motor, 770M (PN 38403)	1
26	Adjustment Screw (PN 31525)	2
27	Bearing Spacer (PN 31529)	1
28	Washer, Flat, 5 × 25, 3 mm Thick (PN 31532)	1
29	Screw, Button Head Cap, M3 × 0.5 - 5 (PN 38737)	4
30	Screw, Socket Head Cap, M5 × 0.8 - 20 (PN 30357)	10

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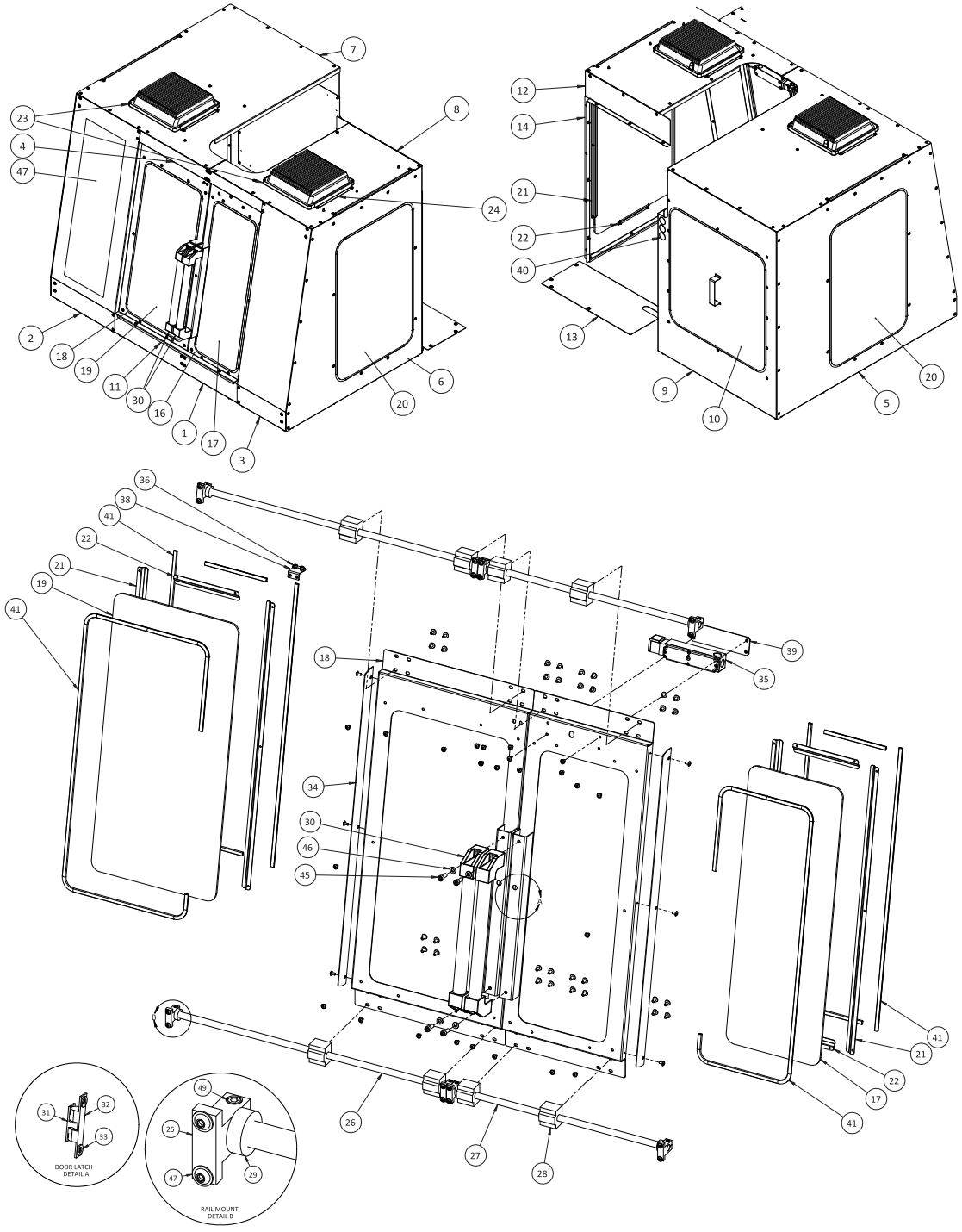
ID	Description	Quantity
31	Screw, Socket Head Cap, M10 × 1.5 - 30 (PN 31894)	4
32	Screw, Socket Head Cap, M6 × 1 - 25 (PN 31685)	4
33	Screw, Socket Head Cap, M12 × 1.75 - 50 (PN 32476)	6
34	Washer, Split Lock, M12 (PN 30321)	10
35	M6 Lock Washer (PN 31379)	4
36	Screw, Socket Head Cap, M10 × 1.5 - 35 (PN 31592)	10
37	Screw, Button Head Cap, M5 × 0.8 - 8 (PN 34636)	7
38	Washer, Split Lock, M5 (PN 31572)	1
39	Screw, Socket Head Cap, M4 × 0.7 - 12 (PN 31360)	4
40	Screw, Button Head Cap, M5 × 0.8 - 10 (PN 35774)	8
41	Z-Axis Ballscrew Assembly, 770 (PN 31434)	1
42	770M Moving Kit (PN 31333)	1

13.21 ENCLOSURE EXPLODED VIEW



13.22 ENCLOSURE PARTS LIST

ID	Description	Quantity
1	Enclosure Panel, 770, Lower Front (PN 37600)	1
2	Enclosure Panel, 770M, Left Front (PN 37603)	1
3	Enclosure Panel, 770M, Right Front (PN 37601)	1
4	Enclosure Panel, 770, Upper Front (PN 37605)	1
5	Enclosure Panel, 770M, Left Side (PN 37604)	1
6	Enclosure Panel, 770M, Right Side (PN 37602)	1
7	Enclosure Panel, 770, Left Top (PN 37614)	1
8	Enclosure Panel, 770, Right Top (PN 37615)	1
9	Enclosure Panel, 770, Left Rear (PN 37616)	1
10	Enclosure Panel, 770, ATC (PN 37617)	1
11	Chip Tray Rail, 770 (PN 37662)	1
12	Enclosure Panel, 770, Right Rear (PN 37619)	1
13	Enclosure Panel, 770M, Splash Shield (PN 38479)	1
14	Enclosure Panel, 770, Splice Plate (PN 38480)	1
15	Enclosure Panel, 770, Column Splice (PN 37618)	1
16	Enclosure Door, 770, Right (PN 37609)	1
17	Window, 770M, Right Door (PN 37624)	1
18	Enclosure Door, 770, Left (PN 37608)	1
19	Window, 770M, Left Door (PN 37623)	1
20	Window, 770, Side (PN 37625)	2
21	Enclosure Window Retainer, 770, Vertical (PN 37620)	8
22	Enclosure Window Retainer, 770, Horizontal (PN 37621)	8
23	LED Floodlight, 50 W (PN 37341)	2
24	Flood Light Retainer (PN 38222)	4
25	Linear Rail Mount (PN 37622)	8
26	Left Door Rail, 770 (PN 37606)	2
27	Right Door Rail, 770 (PN 37607)	2
28	Linear Bearing (PN 37610)	8
29	Door Bumper (PN 38357)	8
30	Handle, 400 mm (PN 37611)	2
31	Enclosure Ball Latch, Male (PN 38483)	1

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ID	Description	Quantity
32	Enclosure Ball Latch, Female (PN 38482)	1
33	Washer, Flat, M5, Stainless Steel (PN 37939)	2
34	Door Seal (PN 37613)	2
35	Locking Door Switch (PN 37352)	1
36	Nut Bar (PN 37585)	1
37	Locking Switch Key (PN 37529)	1
38	Switch Key Bracket (PN 37586)	1
39	Locking Door Switch Installation/Cover Plate (PN 38272)	1
40	Round Plug, 32 mm (PN 37598)	3
41	Sealing Strip, Rubber (PN 38356)	21
42	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	77
43	Screw, Button Head Cap (Flanged), M5 × 0.8 - 10, Stainless Steel (PN 38205)	153
44	Screw, Socket Head Cap, M5 × 0.8 - 20 (PN 30357)	8
45	Screw, Socket Head Cap, M8 × 1.25 - 22 (PN 37190)	4
46	Washer, Flat, M8 (PN 30531)	4
47	Decal, Enclosure, 770M, Front Left Panel (PN 38745)	1

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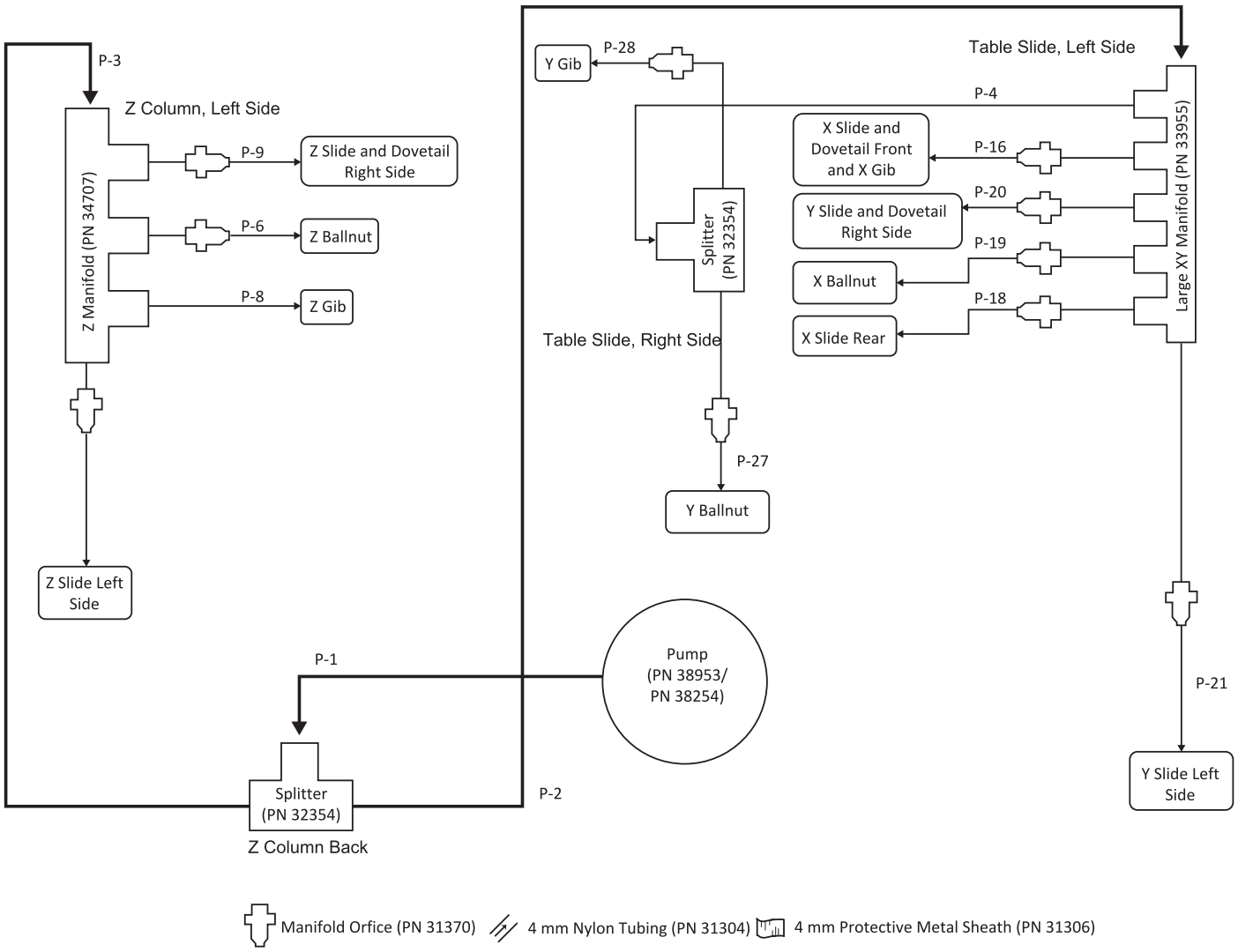
13.23 LUBRICATION/OIL SYSTEM DIAGRAM



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PNEUMATIC SCHEMATICS

IN THIS SECTION, YOU'LL LEARN:

- About the pneumatic schematics for this machine's pneumatic systems.

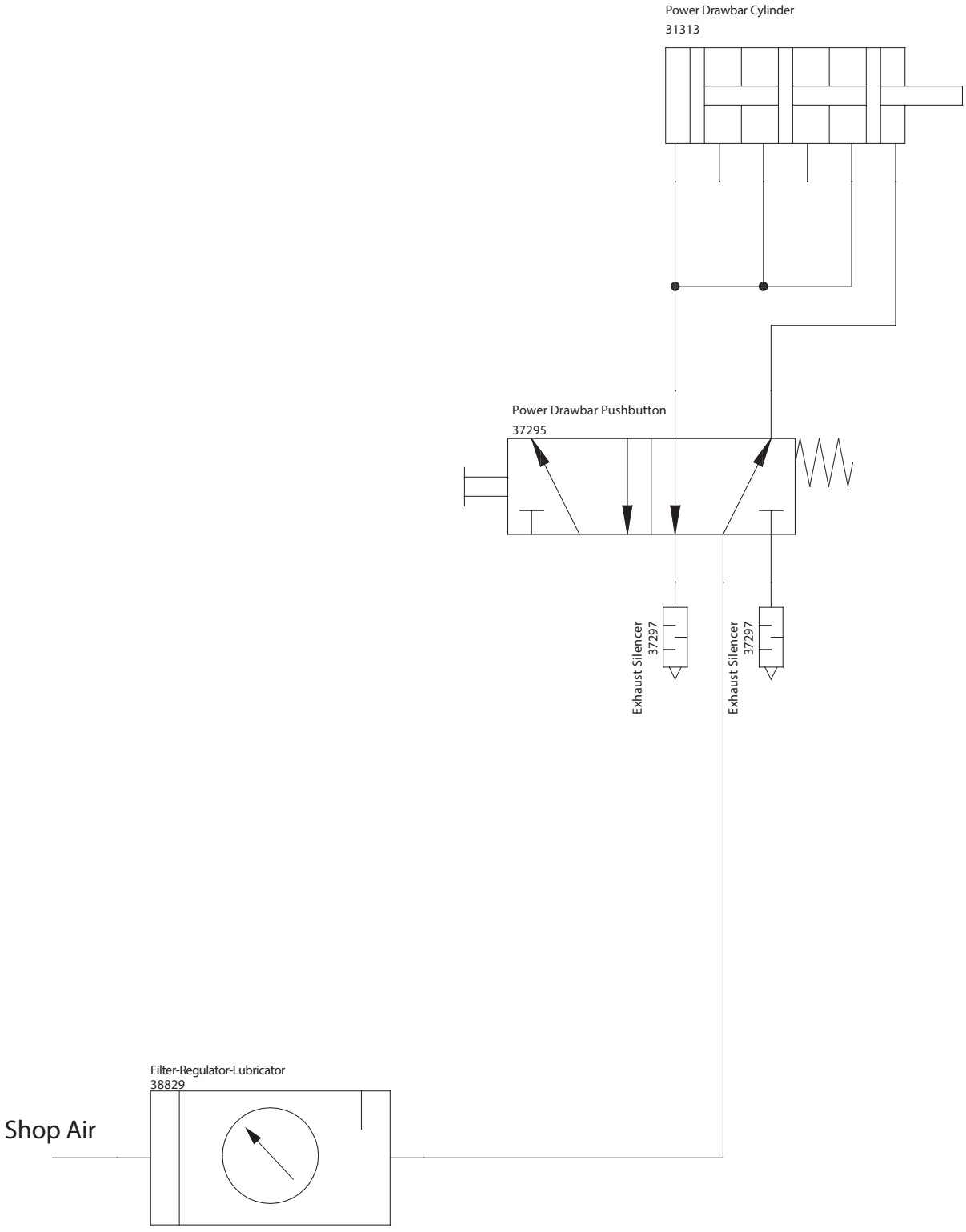
CONTENTS

14.1 Power Drawbar Pneumatics **288**

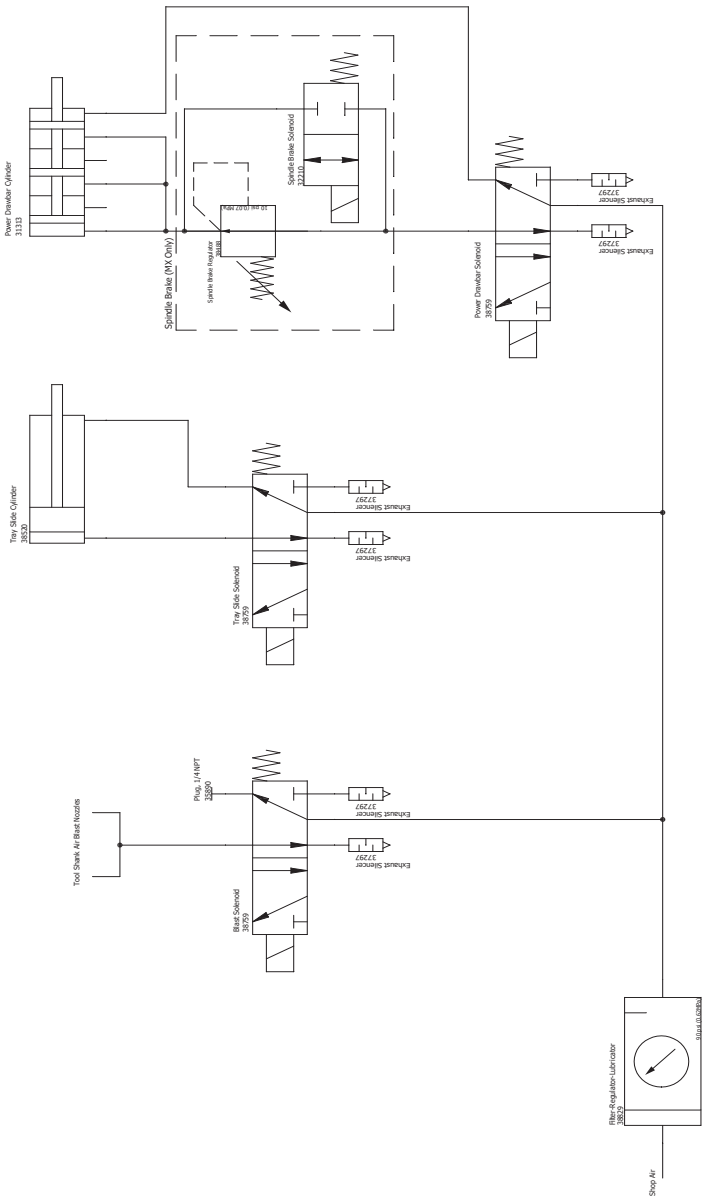
14.2 Automatic Tool Changer (ATC) Pneumatics **289**

14: PNEUMATIC SCHEMATICS

14.1 POWER DRAWBAR PNEUMATICS



14.2 AUTOMATIC TOOL CHANGER (ATC) PNEUMATICS



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ELECTRICAL SCHEMATICS

IN THIS SECTION, YOU'LL LEARN:

- About the electrical schematics for this machine's electronics.

CONTENTS

15.1 115 Vac Power (Sheet 1) 292
15.2 24 Vdc Controls (Sheet 2) 293
15.3 Axis Drive Bus (Sheet 3) 294
15.4 Spindle Drive (Sheet 4) 295
15.5 Machine Control Board (Sheet 5) 296
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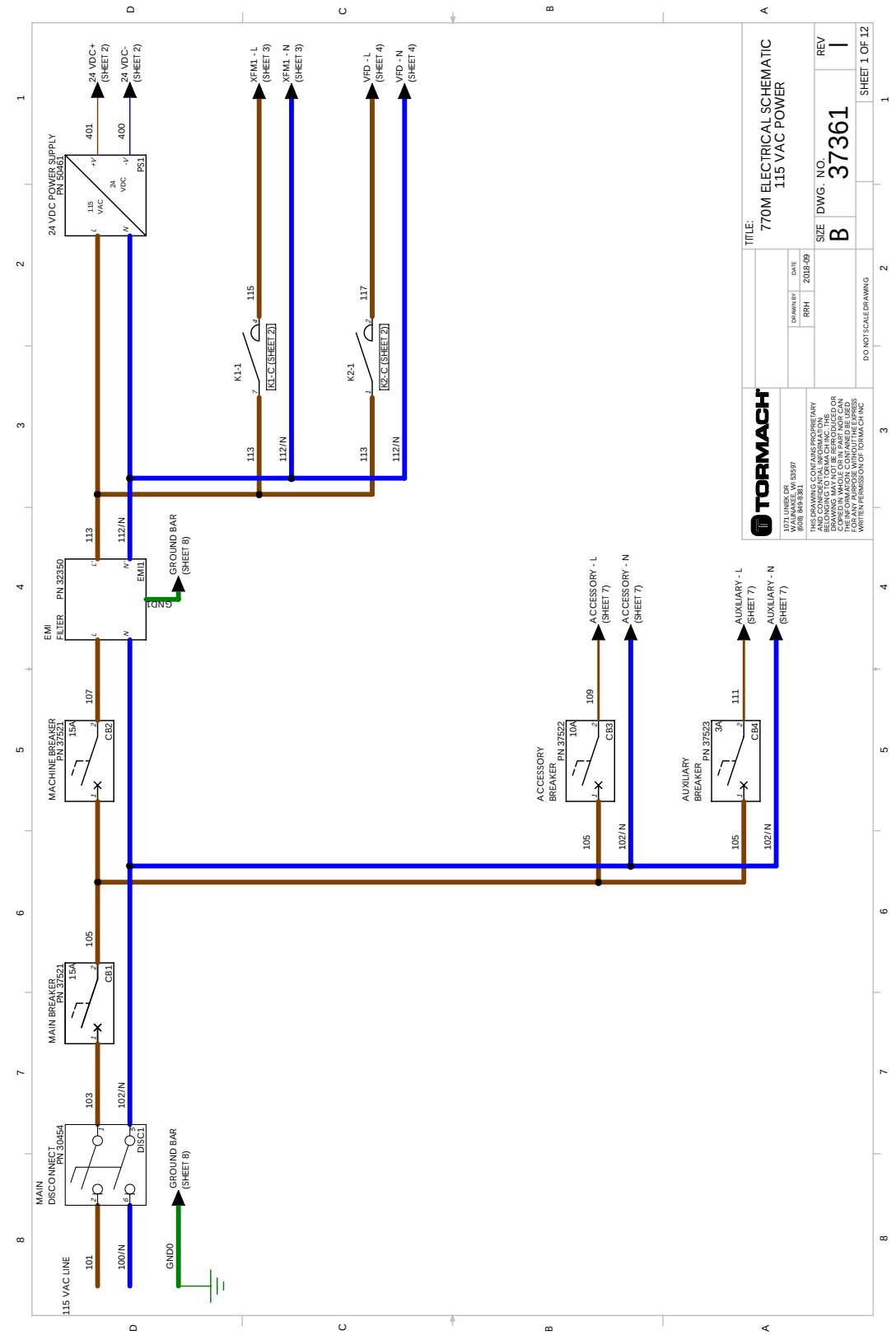
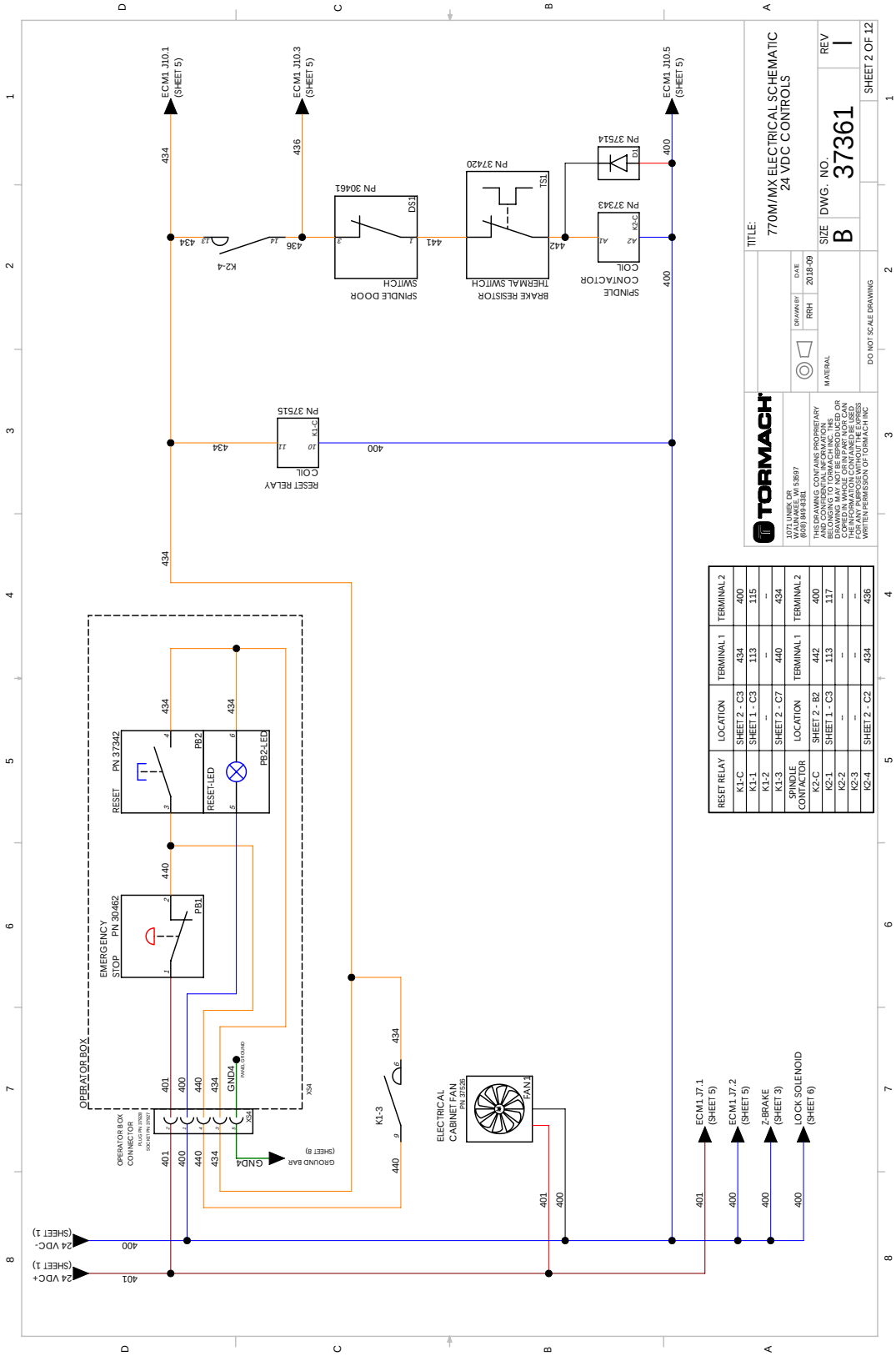
15.8 Grounds (Sheet 8) 299
15.9 Electrical Panel Layout and Fuse Table (Sheet 9) 300
15.10 Operator Box Layout (Sheet 10) 301
15.11 Wiring Table (Sheet 11) 302
15.12 Operator Console Schematic 303

15: ELECTRICAL SCHEMATICS

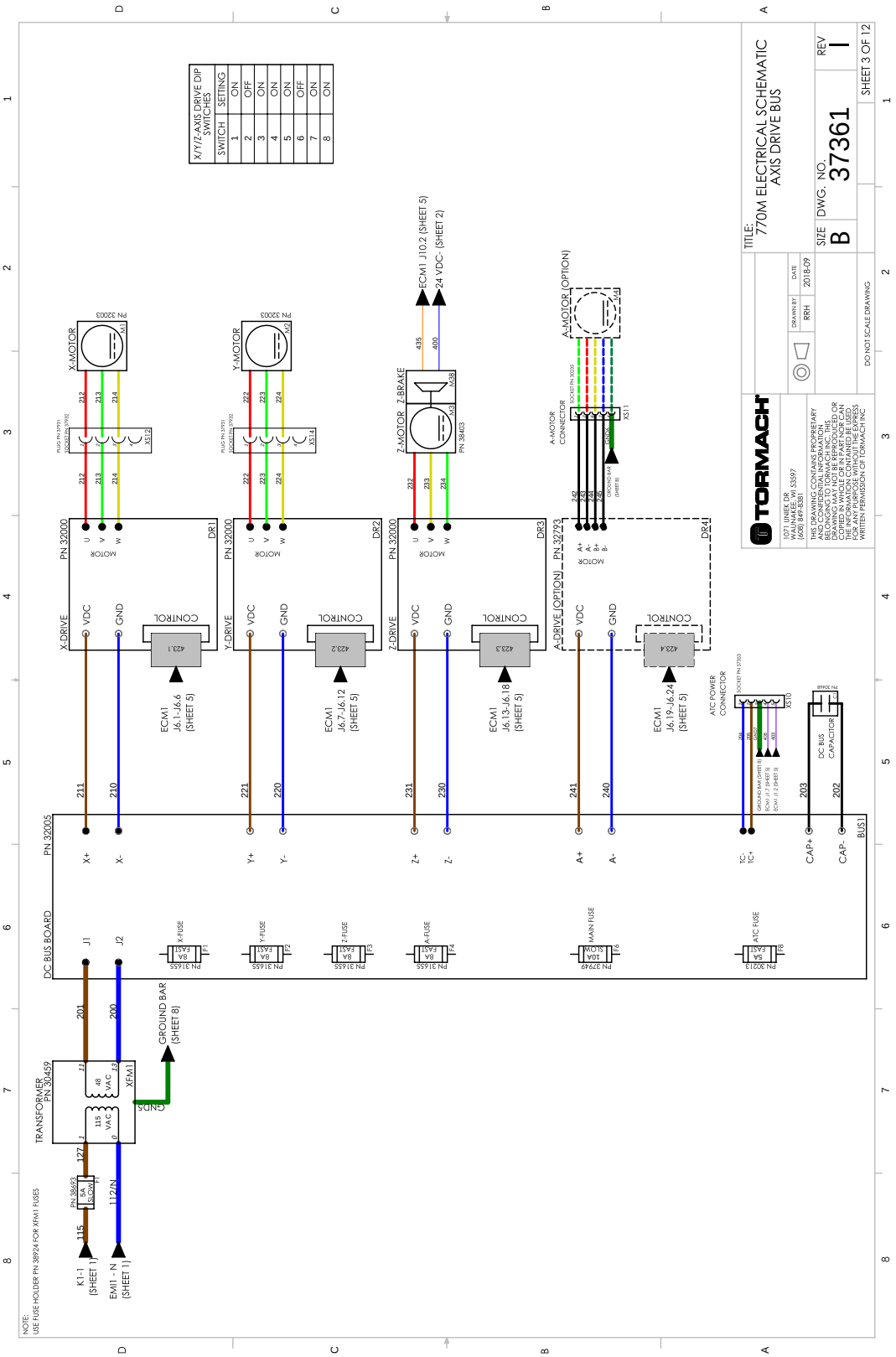
15.1 115 VAC POWER (SHEET 1)



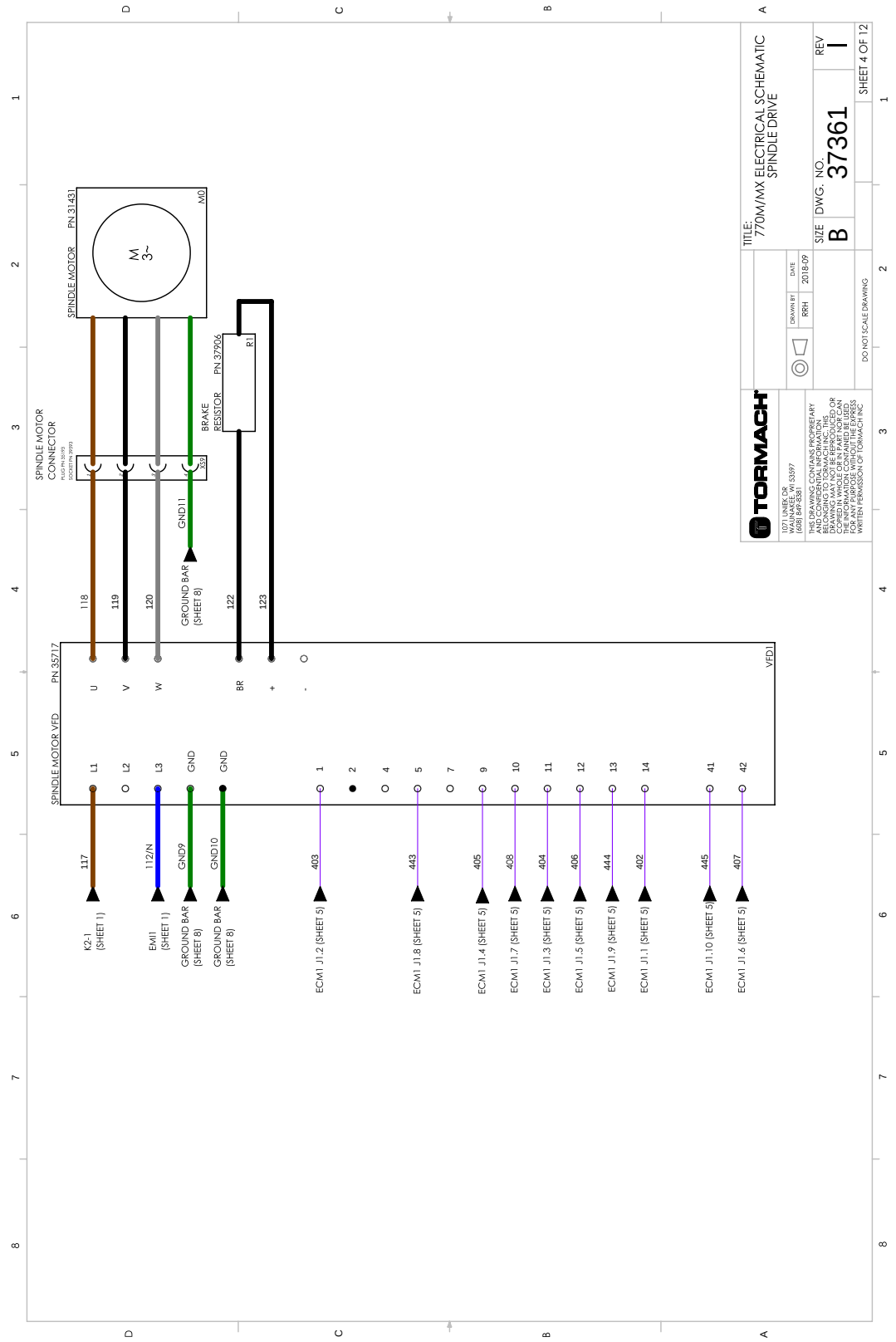
15.2 24 VDC CONTROLS (SHEET 2)



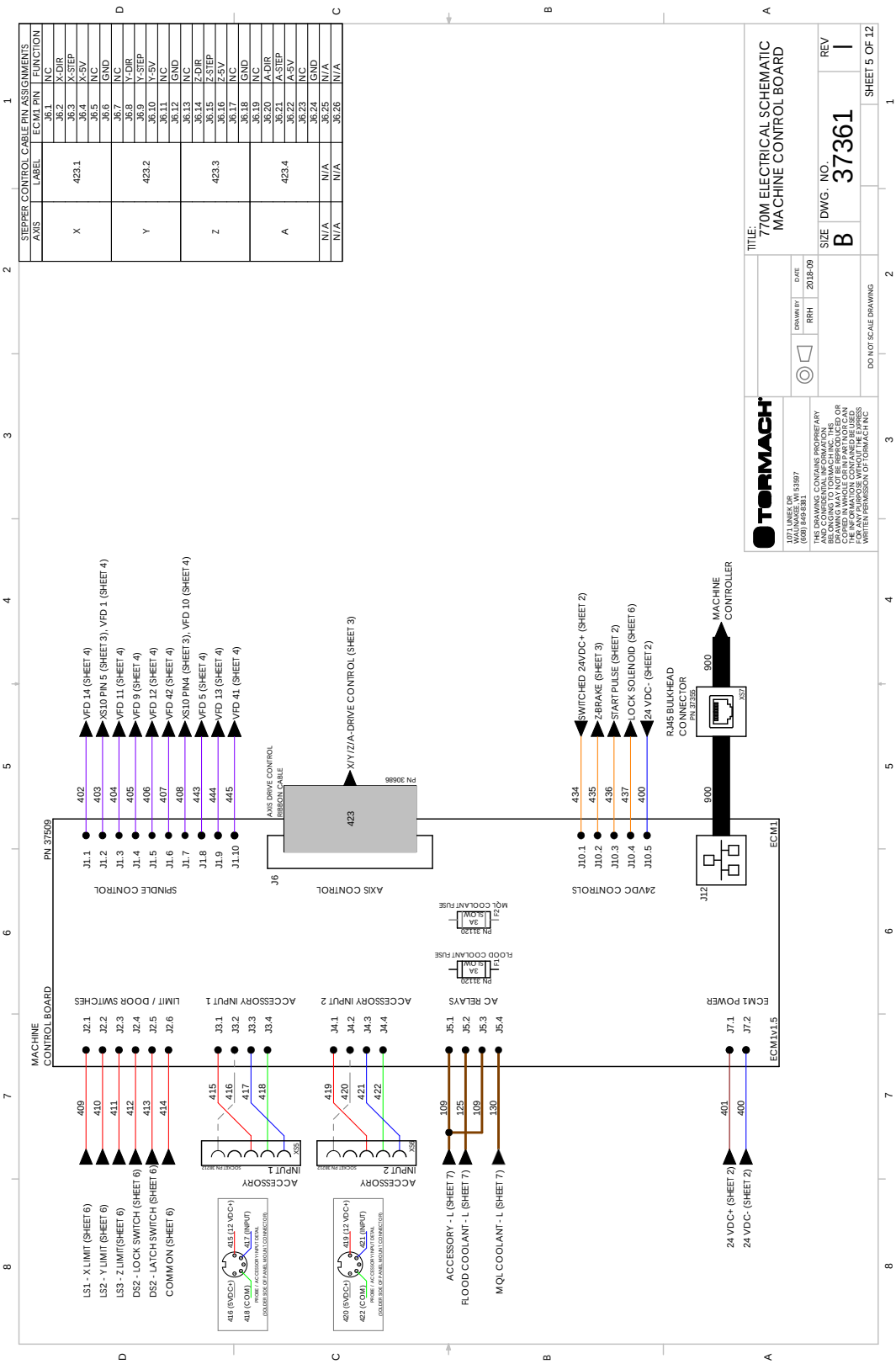
15.3 AXIS DRIVE BUS (SHEET 3)



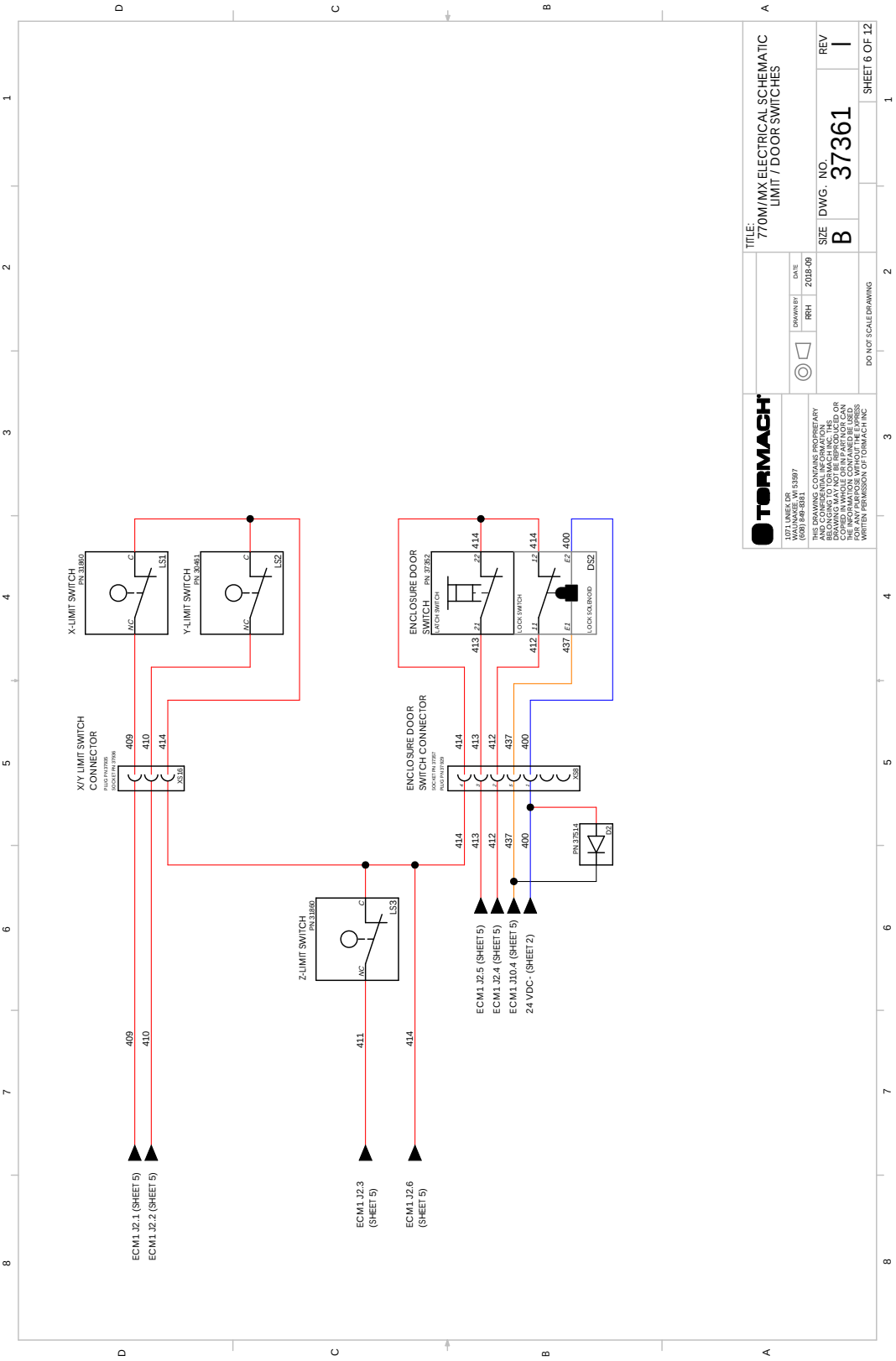
15.4 SPINDLE DRIVE (SHEET 4)



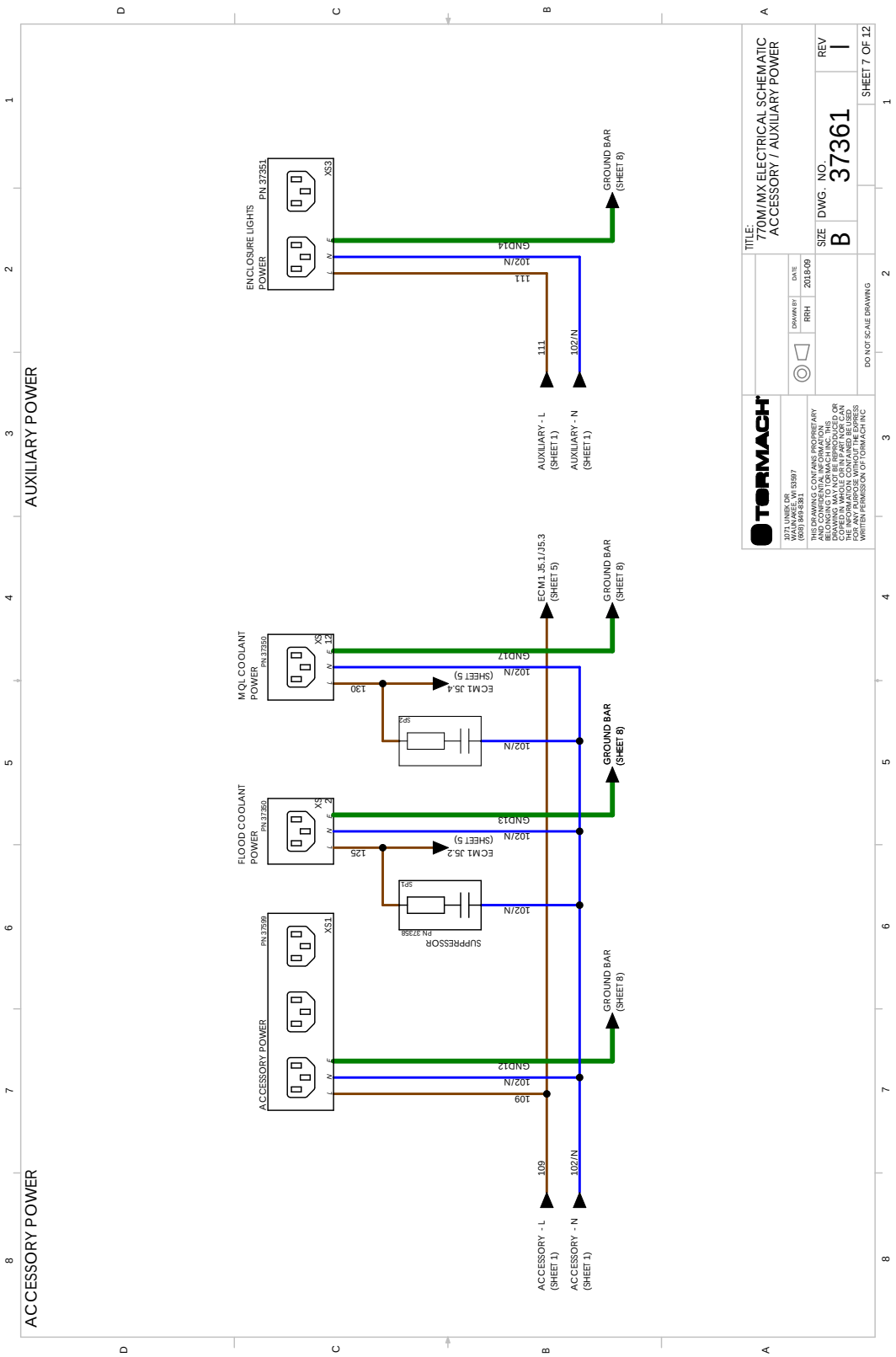
15.5 MACHINE CONTROL BOARD (SHEET 5)



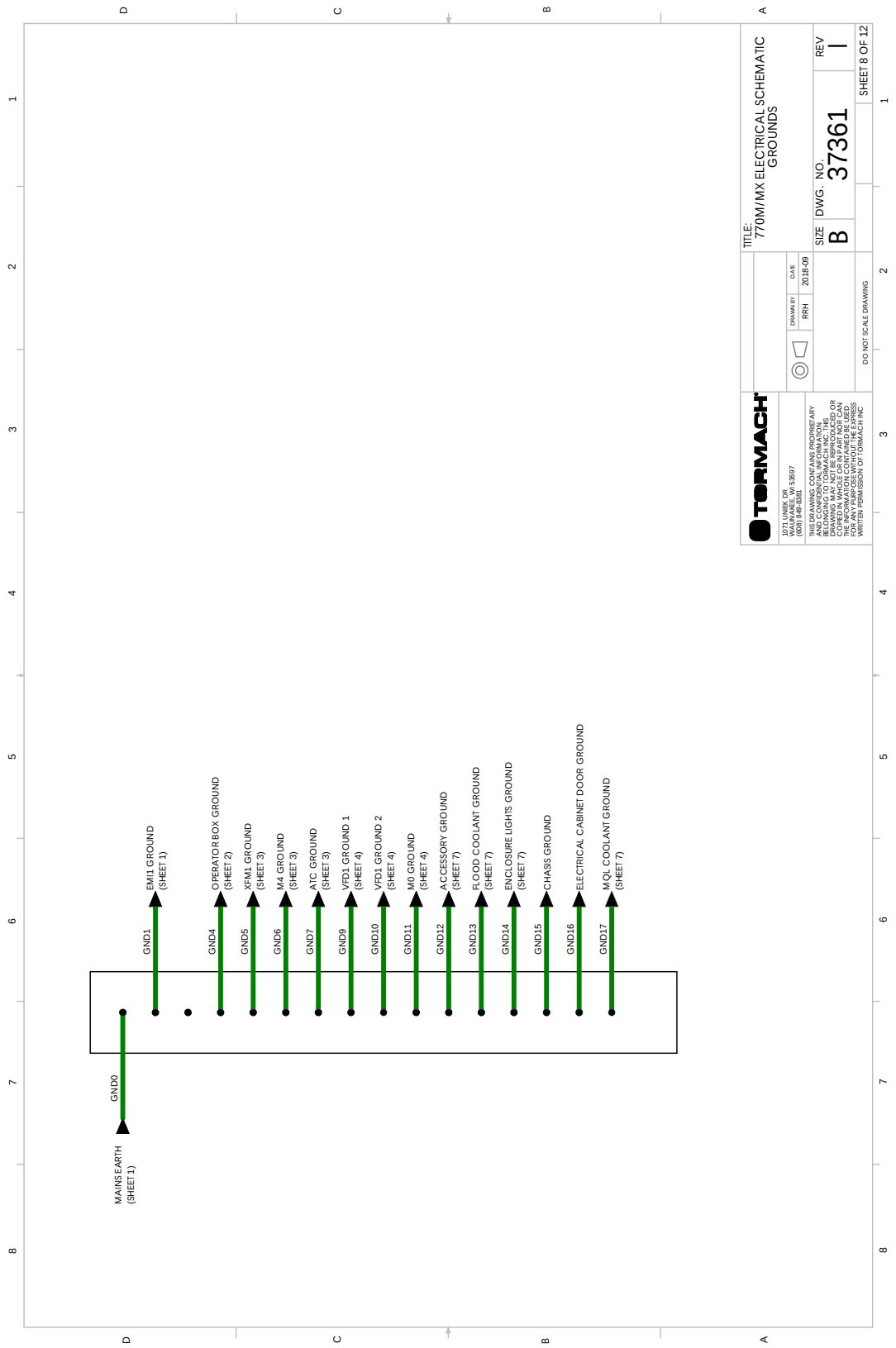
15.6 LIMIT/DOOR SWITCHES (SHEET 6)



15.7 ACCESSORY AND AUXILIARY POWER (SHEET 7)



15.8 GROUNDS (SHEET 8)



15.9 ELECTRICAL PANEL LAYOUT AND FUSE TABLE (SHEET 9)

REF	PN	DESCRIPTION
ECM1	37509	MACHINE CONTROL BOARD
DR1	32000	X-AXIS DRIVER (M ONLY)
DR2	32000	Y-AXIS DRIVER (M ONLY)
DR3	32000	Z-AXIS DRIVER (M ONLY)
DR4	---	A-AXIS DRIVER (OPTION)
PS1	50461	24 VDC POWER SUPPLY
D1	37514	FLYBACK PROTECTION DIODE
D2	37514	FLYBACK PROTECTION DIODE
K1	37515	RESET RELAY
K2	37343	SPINDLE CONTACTOR
BUS1	32005	DC BUS BOARD
VFD1	35714	SPINDLE MOTOR VFD
XFM1	37909	TRANSFORMER
SP1	37358	SUPPRESSOR
CB1	37521	MAIN BREAKER
CB2	37521	MACHINE BREAKER
CB3	37522	ACCESSORY BREAKER
CB4	37523	AUXILIARY BREAKER
EMI1	32350	EMI FILTER
F1	38398	FUSE HOLDER
R1	37906	BRAKE RESISTOR (SIDE OF CABINET)
TS1	37420	BRAKE RESISTOR THERMAL SWITCH (SIDE OF CABINET)
C1	30468	DC BUS CAPACITOR (SIDE OF CABINET)

FUSES TABLE				
COMPONENT	FUSE NO.	AMPERES	SPEED	PN
DC BUS TRANSFORMER XFM1	F1	5A	SLOW	38693
DC BUS BOARD BUS1	F1	8A	FAST	31655
	F2	8A	FAST	31655
	F3	8A	FAST	31655
	F4	8A	FAST	31655
	F6	10A	SLOW	37949
MACHINE CONTROL BOARD ECM1	F8	5A	FAST	30213
	F1	3A	SLOW	31120
	F2	3A	SLOW	31120

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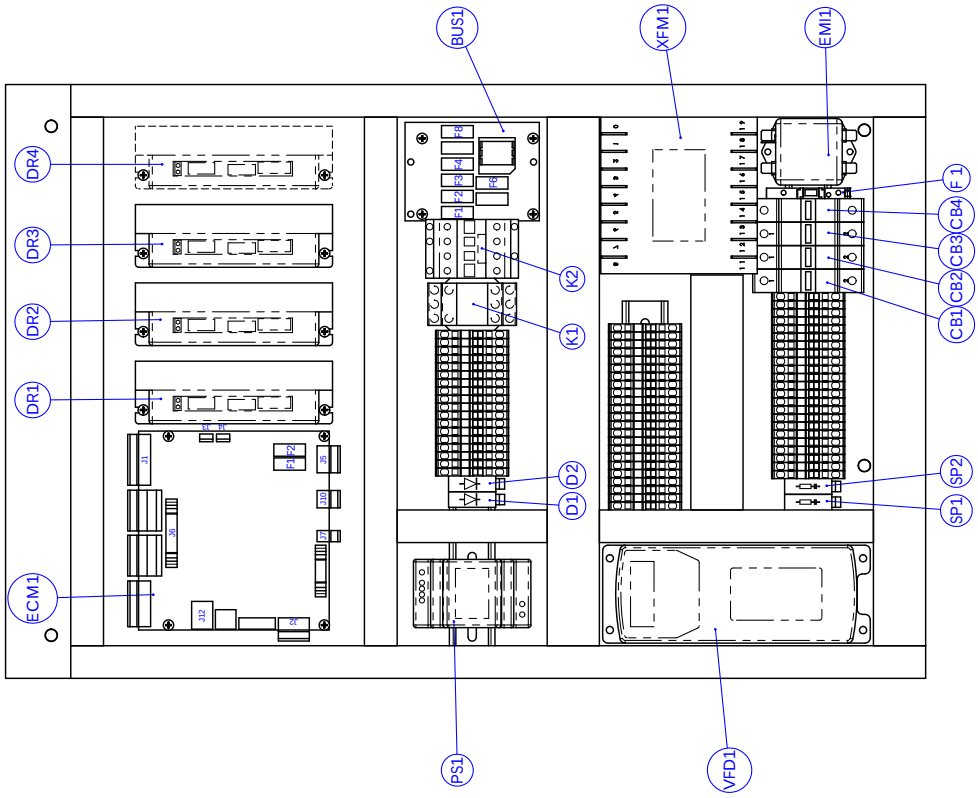
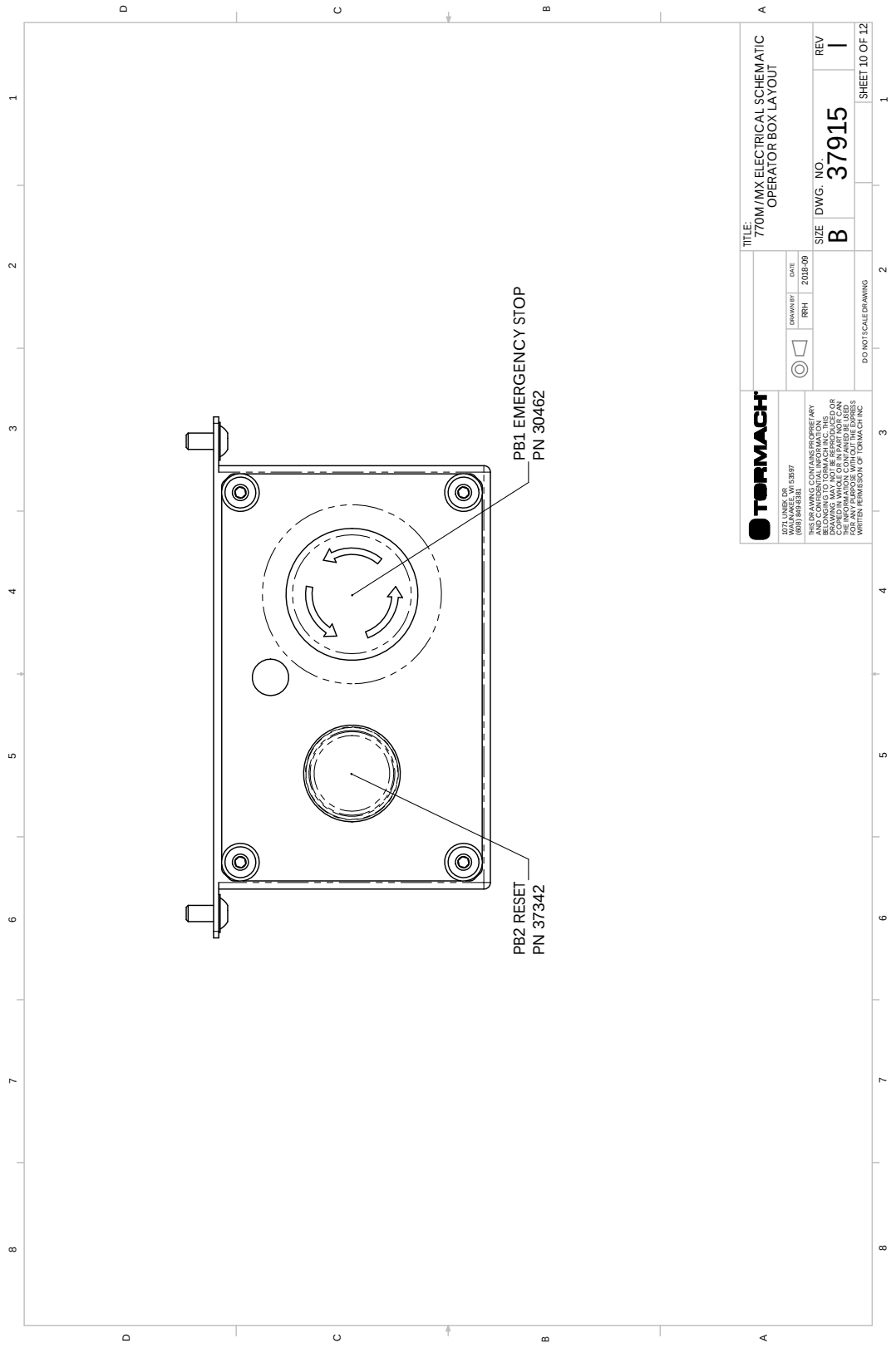
TITLE: 770M/MX ELECTRICAL SCHEMATIC ELECTRICAL PANEL LAYOUT

SIZE: B
DWG. NO.: 37361
REV: I

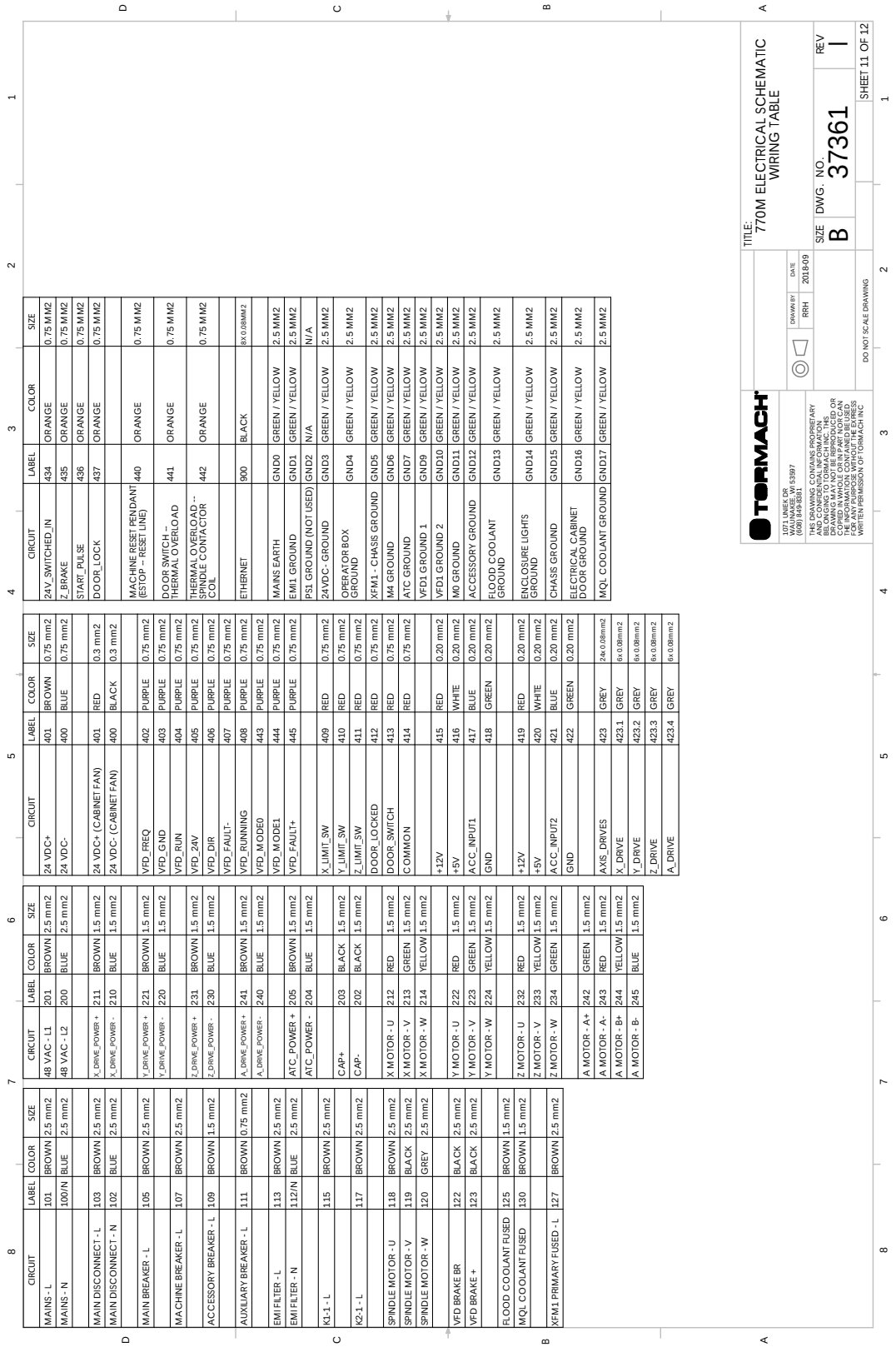
SHEET 9 OF 12



15.10 OPERATOR BOX LAYOUT (SHEET 10)



15.11 WIRING TABLE (SHEET 11)



CIRCUIT	LABEL	COLOR	SIZE
MAINS - L	101	BROWN	2.5 mm2
MAINS - N	100/N	BLUE	2.5 mm2
MAIN DISCONNECT - L	103	BROWN	2.5 mm2
MAIN DISCONNECT - N	102	BLUE	2.5 mm2
MAIN BREAKER - L	105	BROWN	2.5 mm2
MACHINE BREAKER - L	107	BROWN	2.5 mm2
ACCESSORY BREAKER - L	109	BROWN	1.5 mm2
AUXILIARY BREAKER - L	111	BROWN	0.75 mm2
EMI FILTER - L	113	BROWN	2.5 mm2
EMI FILTER - N	112/N	BLUE	2.5 mm2
K1-1 - L	115	BROWN	2.5 mm2
K2-1 - L	117	BROWN	2.5 mm2
SPINDLE MOTOR - U	118	BROWN	2.5 mm2
SPINDLE MOTOR - V	119	BLACK	2.5 mm2
SPINDLE MOTOR - W	120	GREY	2.5 mm2
VFD BRAKE BR	122	BLACK	2.5 mm2
VFD BRAKE +	123	BLACK	2.5 mm2
FLOOD COOLANT FUSED	125	BROWN	1.5 mm2
MQL COOLANT FUSED	130	BROWN	1.5 mm2
XFM1 PRIMARY FUSED - L	127	BROWN	2.5 mm2

CIRCUIT	LABEL	COLOR	SIZE
48 VAC - L1	201	BROWN	2.5 mm2
48 VAC - L2	200	BLUE	2.5 mm2
X_DRIVE_POWER +	211	BROWN	1.5 mm2
X_DRIVE_POWER -	210	BLUE	1.5 mm2
Y_DRIVE_POWER +	221	BROWN	1.5 mm2
Y_DRIVE_POWER -	220	BLUE	1.5 mm2
Z_DRIVE_POWER +	231	BROWN	1.5 mm2
Z_DRIVE_POWER -	230	BLUE	1.5 mm2
A_DRIVE_POWER +	241	BROWN	1.5 mm2
A_DRIVE_POWER -	240	BLUE	1.5 mm2
ATC_POWER +	205	BROWN	1.5 mm2
ATC_POWER -	204	BLUE	1.5 mm2
CAP+	203	BLACK	1.5 mm2
CAP-	202	BLACK	1.5 mm2
X MOTOR - U	212	RED	1.5 mm2
X MOTOR - V	213	GREEN	1.5 mm2
X MOTOR - W	214	YELLOW	1.5 mm2
Y MOTOR - U	222	RED	1.5 mm2
Y MOTOR - V	223	GREEN	1.5 mm2
Y MOTOR - W	224	YELLOW	1.5 mm2
Z MOTOR - U	232	RED	1.5 mm2
Z MOTOR - V	233	YELLOW	1.5 mm2
Z MOTOR - W	234	GREEN	1.5 mm2
A MOTOR - A+	242	GREEN	1.5 mm2
A MOTOR - A-	243	RED	1.5 mm2
A MOTOR - B+	244	YELLOW	1.5 mm2
A MOTOR - B-	245	BLUE	1.5 mm2

CIRCUIT	LABEL	COLOR	SIZE
24 VDC+	401	BROWN	0.75 mm2
24 VDC-	400	BLUE	0.75 mm2
24 VDC+ (CABINET FAN)	401	RED	0.3 mm2
24 VDC- (CABINET FAN)	400	BLACK	0.3 mm2
VFD_FREQ	402	PURPLE	0.75 mm2
VFD_GND	403	PURPLE	0.75 mm2
VFD_RUN	404	PURPLE	0.75 mm2
VFD_24V	405	PURPLE	0.75 mm2
VFD_DIR	406	PURPLE	0.75 mm2
VFD_FAULT-	407	PURPLE	0.75 mm2
VFD_RUNNING	408	PURPLE	0.75 mm2
VFD_MODE0	443	PURPLE	0.75 mm2
VFD_MODE1	444	PURPLE	0.75 mm2
VFD_FAULT+	445	PURPLE	0.75 mm2
X_LIMIT_SW	409	RED	0.75 mm2
Y_LIMIT_SW	410	RED	0.75 mm2
Z_LIMIT_SW	411	RED	0.75 mm2
DOOR_LOCKED	412	RED	0.75 mm2
DOOR_SWITCH	413	RED	0.75 mm2
COMMON	414	RED	0.75 mm2
+12V	415	RED	0.20 mm2
+5V	416	WHITE	0.20 mm2
ACC_INPUT1	417	BLUE	0.20 mm2
GND	418	GREEN	0.20 mm2
+12V	419	RED	0.20 mm2
+5V	420	WHITE	0.20 mm2
ACC_INPUT2	421	BLUE	0.20 mm2
GND	422	GREEN	0.20 mm2
AXIS_DRIVES	423	GREY	24x 0.08mm2
X_DRIVE	423.1	GREY	6x 0.08mm2
Y_DRIVE	423.2	GREY	6x 0.08mm2
Z_DRIVE	423.3	GREY	6x 0.08mm2
A_DRIVE	423.4	GREY	6x 0.08mm2

CIRCUIT	LABEL	COLOR	SIZE
24V_SWITCHED_IN	434	ORANGE	0.75 MM2
Z_BRAKE	435	ORANGE	0.75 MM2
START_PULSE	436	ORANGE	0.75 MM2
DOOR_LOCK	437	ORANGE	0.75 MM2
MACHINE RESET PENDANT (ESTOP -- RESET LINE)	440	ORANGE	0.75 MM2
DOOR SWITCH -- THERMAL OVERLOAD	441	ORANGE	0.75 MM2
THERMAL OVERLOAD -- SPINDLE CONTACTOR COIL	442	ORANGE	0.75 MM2
ETHERNET	900	BLACK	8X 0.08MM2
MAINS EARTH	GND0	GREEN / YELLOW	2.5 MM2
EMI1 GROUND	GND1	GREEN / YELLOW	2.5 MM2
PS1 GROUND (NOT USED)	GND2	N/A	N/A
24VDC- GROUND	GND3	GREEN / YELLOW	2.5 MM2
OPERATOR BOX GROUND	GND4	GREEN / YELLOW	2.5 MM2
XFM1 - CHASIS GROUND	GND5	GREEN / YELLOW	2.5 MM2
M4 GROUND	GND6	GREEN / YELLOW	2.5 MM2
ATC GROUND	GND7	GREEN / YELLOW	2.5 MM2
VFD1 GROUND 1	GND9	GREEN / YELLOW	2.5 MM2
VFD1 GROUND 2	GND10	GREEN / YELLOW	2.5 MM2
M0 GROUND	GND11	GREEN / YELLOW	2.5 MM2
ACCESSORY GROUND	GND12	GREEN / YELLOW	2.5 MM2
FLOOD COOLANT GROUND	GND13	GREEN / YELLOW	2.5 MM2
ENCLOSURE LIGHTS GROUND	GND14	GREEN / YELLOW	2.5 MM2
CHASIS GROUND	GND15	GREEN / YELLOW	2.5 MM2
ELECTRICAL CABINET DOOR GROUND	GND16	GREEN / YELLOW	2.5 MM2
MQL COOLANT GROUND	GND17	GREEN / YELLOW	2.5 MM2

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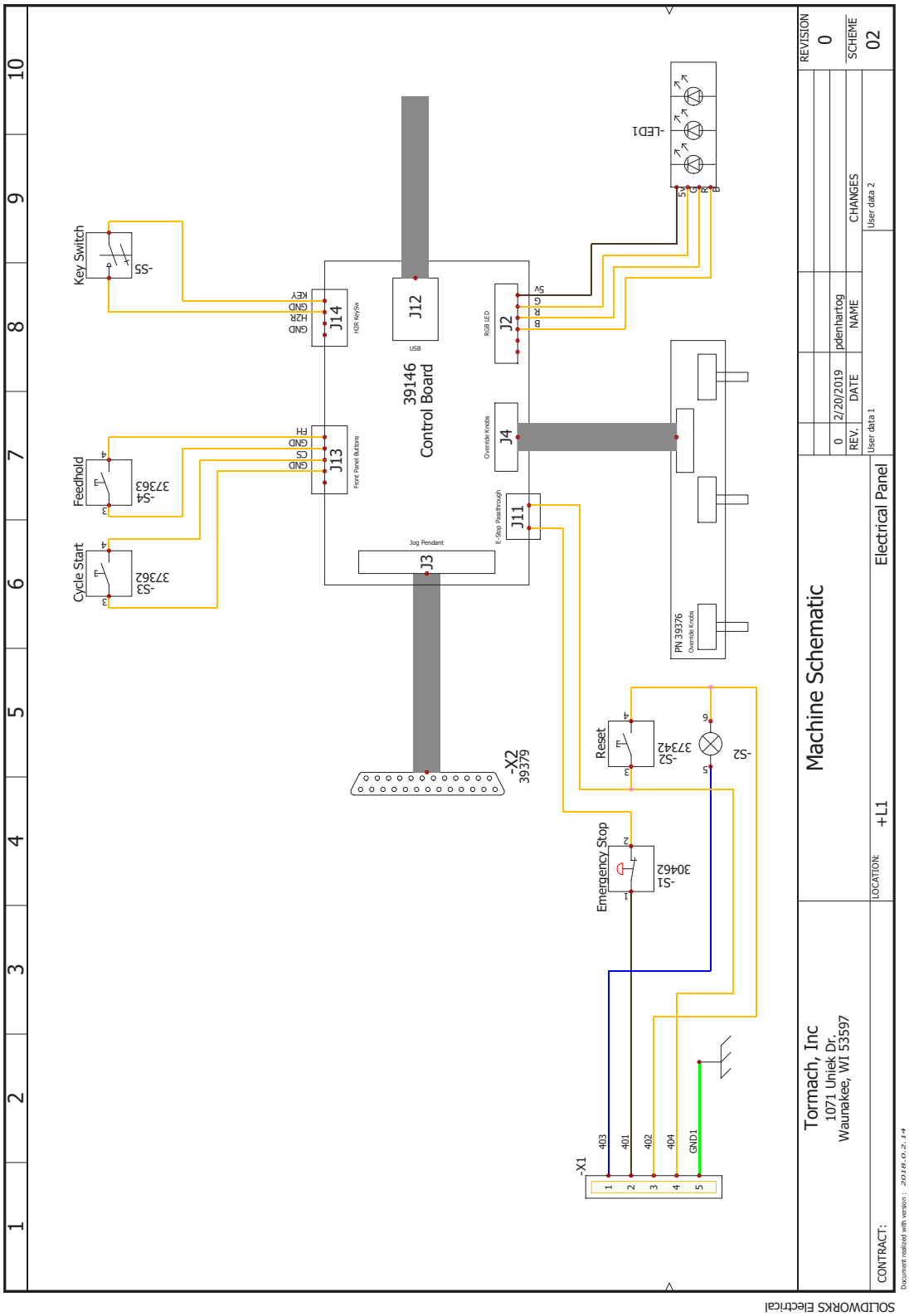
DRAWN BY: RRH
DATE: 2018-09

DO NOT SCALE DRAWING

TITLE: 770M ELECTRICAL SCHEMATIC WIRING TABLE

SIZE: B
DWG. NO. 37361
REV I

SHEET 11 OF 12

15.12 OPERATOR CONSOLE SCHEMATIC