OPERATOR'S MANUAL

Original Instructions

Version 1223A

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Unless otherwise noted, companies, names, and various data used in examples are fictitious.

To the Reader

We're dedicated to continually improving our documentation and products, and welcome any clarifications, corrections, or suggestions.

Credits

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 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

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, dust collection systems, and machining parameters.
- Machining of wood, plastic materials, and soft, non-ferrous metals.

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*

1.2.2 Occupational Safety and Health Administration (OSHA)

- **OSHA 1910.212** *General Requirements for All Machines*

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

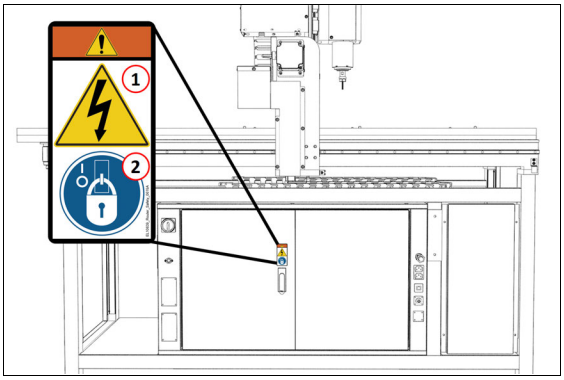


Figure 1-1: Example of a safety decal on the electrical cabinet door.

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

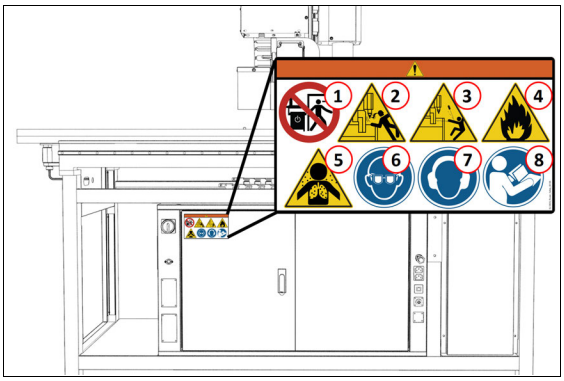


Figure 1-2: Example of a safety decal next to the Main Disconnect.

1. **Don't Operate Unattended.** Never allow the machine to run unattended. The machine's spinning tool generates friction and heat — chips, dust, or materials can start on fire. Before operating the machine in any way, you must verify that you're using the correct tools for the material. During operations, you must be prepared to stop the cut if something seems incorrect or unsafe.
2. **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.
3. **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.
4. **WARNING! Fire Hazard.** The machine is 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.

5. **WARNING! Inhalation Hazard.** The machine does 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.
6. **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+.
7. **Personal Protective Equipment: Ears.** Prevent injury by always wearing ear protection when you expect the machine or the machining processes to exceed safe exposure limits.
8. **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 Head

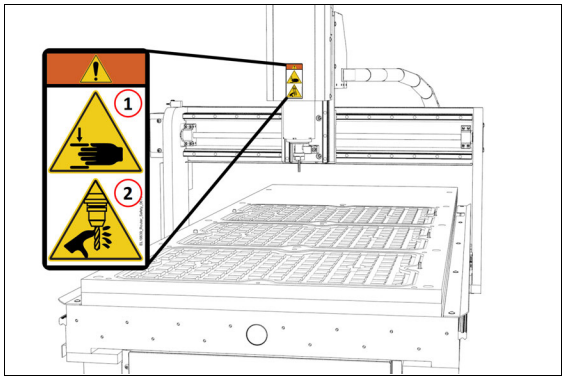


Figure 1-3: Example of a safety decal on the spindle nose.

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.

On the Gantry and the Spindle Head

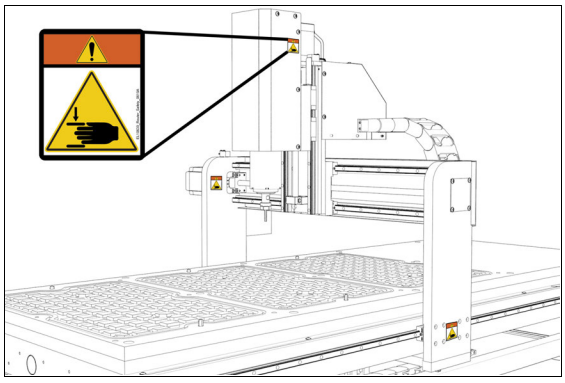


Figure 1-4: Example of safety decals on the spindle head.

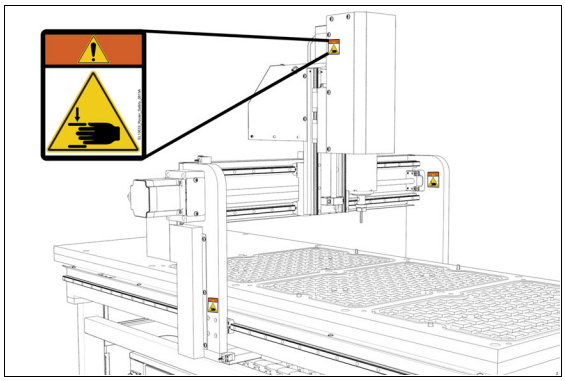


Figure 1-5: Example of safety decals on the left side of the machine.

- **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.

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.

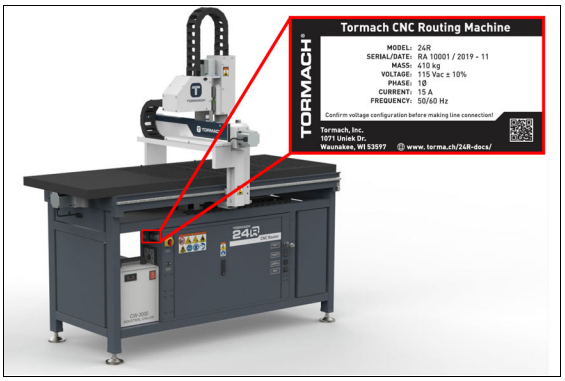


Figure 1-6: Example of the serial number plate on the side of the electrical cabinet.

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

- Verify that only qualified machinery maintenance professionals install, set up, or perform maintenance on this machine.
- Verify that a fire extinguisher is accessible to the work area.
- Verify that a proper dust collection system is installed. Cutting certain materials (like MDF or other wood products) can create dust, which could create a deflagration or explosion hazard. To identify each material's specific requirements, refer to its safety data sheet (SDS).
  For more information about the prevention of fire and dust explosions, see nfpa.org or csb.gov.
- 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.
- 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 use the machine table as a workbench.
- Never lean heavy materials against the gantry, guide rails, or machine table.
- Never operate the machine in an explosive (ATEX) atmosphere. Such explosive atmospheres include explosive gases, vapors, mists, powders, and dusts.
- Never use pressurized air to clean the machine.
- Never install the machine near sinks or faucets, or below water supply pipes and plumbing. Condensation or water splashes can damage the spoil boards or electrical equipment.

1.4.2 Operational Safety

General

- Understand that the machine is automatically controlled and can start at any time.
- 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.
  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.
- Removing any cut materials.
- 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's motion envelope.

- 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 materials that may have sharp edges or splinters, wear cut-resistant gloves and protective clothing.
- When machining materials that create dust, use a proper dust collection system.
- When putting heavy or large materials onto the machine table, work with an assistant.
- 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 20).
- Never remove any cut materials while the machine is running.
- Never use the machine as a workbench or hammer on the table surface.
- Never enter the machining envelope.
- Never reach around a guard.
- Never allow the machine to run unattended.
- Never put your hands on the machine's rails.
- 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.
  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.
- Never use dull or gummy tools.

Workholding

- Secure workpieces with appropriate workholding devices.
- 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.
- Never use your hands to hold the workpiece during machining operations.

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 33).
- 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.

ABOUT YOUR MACHINE

IN THIS SECTION, YOU'LL LEARN:

- About this machine's specifications.

CONTENTS

2.1 PERFORMANCE EXPECTATIONS

2.1.1 Cutting Performance

This machine is capable of cutting a wide variety of materials (for information, see "Intended Use" (page 20)) 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** 10,000 rpm to 24,000 rpm
- **Spindle Power Rating** 2 hp (1.5 kW)
- **Maximum Feed Rate** 200 IPM (5.0 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** 0.00025" (0.006 mm)

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

- **Ball Screw Positional Accuracy** ±0.002 in./ft (±50 micron/300 mm)
- **Repeatability** ±0.001" (±0.0254 mm)

2.2 MACHINE SPECIFICATIONS

Travels	
X-Axis	24.75" (628 mm)
Y-Axis	55.75" (1416 mm)
Z-Axis	6.7" (170 mm)
Spindle	
Spindle Power	2 hp (1.5 kW)
Spindle Type	Electrospindle With Reverse
Minimum Speed	10,000 rpm
Maximum Speed	24,000 rpm
Cooling	Liquid
Spindle Taper	ER20
Thread Machining	Thread Mill
Maximum Feed Rate	
X-, Y-, and Z-Axis	200 IPM (5.0 m/min)
Power	
Primary Power Required	Single-Phase 115 Vac, 50/60 Hz
Recommended Circuit Amperage	Dedicated 15 A breaker
Machine Specifications	
Table Size	26.7" × 65" (680 mm × 1651 mm)
Table Type	Integrated Vacuum Table
Gantry Clearance	6" (154 mm)
Machine Footprint	71" × 39" (1.8 m × 1 m)
Overall System Height	77" (1.9 m)
Typical System Weight	900 lb (408 kg)
Linear Motion Components	
Axis Motor	Stepper Driven
Guideways	Precision Linear Guideway
Ball Screw Diameter	16 mm
Machine Construction	
Stand	Welded Steel
Machine Base	Cast Iron

Gantry Bridge	Aluminum
Gantry Supports	Aluminum
Controller	
Control System	PathPilot (v2.4.x or newer)
Resolution and Accuracy	
Resolution	0.00025" (0.006 mm)
Ball Screw Positional Accuracy	±0.002 in./ft (±50 micron/300 mm)
Repeatability	±0.001" (±0.0254 mm)

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

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 a fire extinguisher within the work area.
- Has a dust collection system installed and operational.
- 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** 71" × 39" (1.8 m × 1 m)
- **Machine Height** 77" (1.9 m)

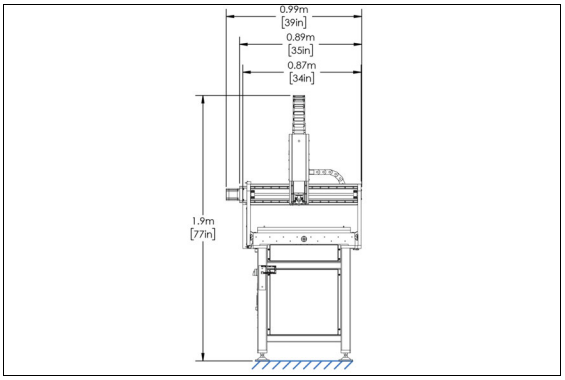


Figure 3-1: Dimensions of the machine itself, as viewed from the front.

- **Typical System Footprint** 119" × 71" (3 m × 1.8 m)

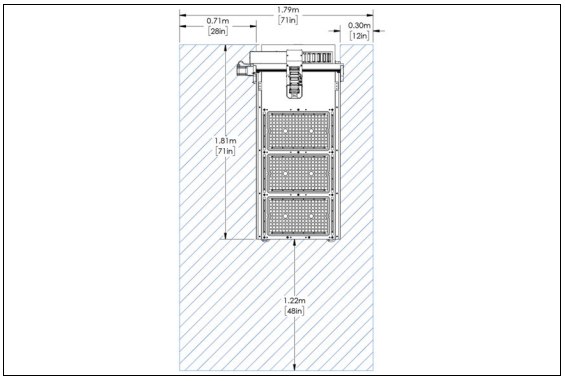


Figure 3-2: Dimensions of the machine and it's required added space, as viewed from above.

3.1.3 Operator Workstation Reference

The typical operator workstation is the area in front of the Controller Arm, as shown in the following image.

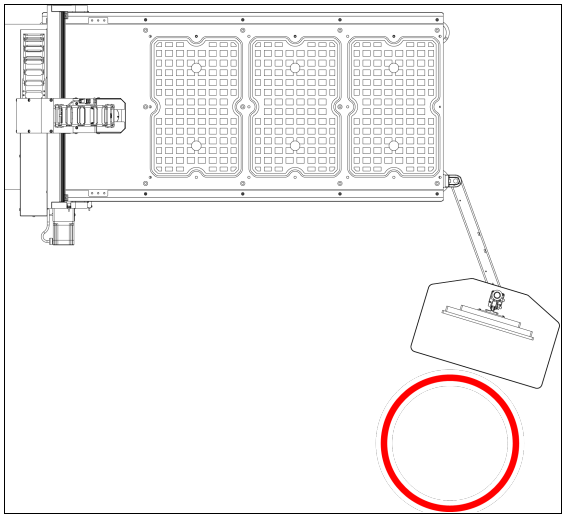


Figure 3-3: Example of the typical operator workstation.

For information on the machine controls, go to "System Basics" (page 77).

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, air compressors, or dust collectors.

  > **Note:** You must use a separate circuit breaker for the required dust collector.

- **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).

INSTALLATION

IN THIS SECTION, YOU'LL LEARN:

- About the installation process required for this machine.

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

CONTENTS

4: INSTALLATION

4.1 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.

4.1.1 Packing List

The following items are included with your 24R (PN 39532):

- 24R Machine Owner's Kit (PN 39534)
- CW3000 Chiller (PN 35161)
- Chiller Alarm Cable (PN 50381)
- Tormach Tool Bag

The Tormach tool bag contains the following tools and items:

- 6 mm Vacuum Gasket (PN 50362), 6 m
- 18 mm - 21 mm Wrench (PN 50358)
- 30 mm - 27 mm Wrench (PN 50357)
- Adjustable Wrench (PN 50359)
- Dust Shoe (PN 50375)
- ER20 Collet: 1/4 in. (PN 30120)
- ER20 Collet Nut
- Grease Gun (PN 50360)
- Metric Hex Wrench Set (PN 50361)
- Operator box

The machine owner's kit contains the following items:

- Black nylon cable tie, 4
- Controller/Monitor Cable (PN 39042), 3
- Ethernet Cable (PN 50383), 2000 mm
- Grease Nozzle Kit (PN 50389)
- M5 × 25 mm screw, 4
- M5 nut, 4
- Operator Box Drill Template (TD10713)
- Operator's Manual (PN 39535)

4.1.2 Installation Tools and Items

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

- 2 in. × 6 in. × 8 in. board, 40
- 4 in. × 4 in. × 6 ft visual grade #2 (or higher) board, 2
- #5 drill bit
- Combination wrenches:
  - 18 mm - 21 mm combination wrench (provided in the tool bag)
  - 30 mm - 27 mm combination wrench (provided in the tool bag)
- Carpenter's level
- Dead-blow hammer (or similar)
- Distilled water
- Drill
- Ladder (optional)
- Metric hex wrench set (provided in the tool bag)
- Pallet jack
- Phillips screwdriver
- Pry bar
- Safety eyewear that meets ANSI Z87+
- Snips
- Socket wrench and an 8 mm (5/16 in.) socket
- Tape
- Work gloves

- Wrenches:
  - 8 mm wrench
  - 16 mm wrench
  - 21 mm wrench
  - 22 mm wrench
  - 24 mm wrench
  - Adjustable wrench (provided in the tool bag)

4.2 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).

4.3 UNPACK THE MACHINE CRATE

Tools and Items Required

- Pallet jack
- Safety eyewear that meets ANSI 787+
- Snips
- Socket wrench and 8 mm (5/16 in.) socket
- Work gloves

> ⚠ **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. Remove the screws from the shipping crate with a socket wrench and an 8 mm (5/16 in.) socket. Start with removing the screws securing the top, followed by the four sides.

   > **Note:** To access the screws on the top of the shipping crate, you may need a ladder.

4. Remove and discard the plastic wrap from the machine.
5. Cut and remove the shipping straps securing the water chiller and the stand end panel to the machine stand, and set both aside for later installation.

Figure 4-1: Water chiller packaged for shipping inside of the machine stand.

6. Remove the tool bag from the machine stand, and set it aside for later use.

   The Tormach tool bag contains the following tools and items:

   - 6 mm Vacuum Gasket (PN 50362), 6 m
   - 18 mm - 21 mm Wrench (PN 50358)
   - 30 mm - 27 mm Wrench (PN 50357)
   - Adjustable Wrench (PN 50359)
   - Dust Shoe (PN 50375)
   - ER20 Collet: 1/4 in. (PN 30120)
   - ER20 Collet Nut
   - Grease Gun (PN 50360)
   - Metric Hex Wrench Set (PN 50361)
   - Operator box

7. Remove and discard all protective shipping materials from the machine, and cut and remove any remaining shipping straps.
8. Remove the desiccant packet from the Z-axis. If it's not on the Z-axis, it may have fallen onto the machine table during shipping.
9. 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.

4.4 LIFT AND MOVE THE MACHINE

Tools and Items Required

- 2 in. × 6 in. × 8 in. board (block), 40
- 4 in. × 4 in. × 6 ft board (support), 2
- 8 mm wrench
- Adjustable wrench (or, if desired, a 22 mm wrench)
- Pallet jack

The easiest way to lift and move the machine off of the pallet is to use a forklift. If you don't have a forklift available, we recommend lifting the machine with 4 in. × 4 in. × 6 ft boards (supports) and 2 in. × 6 in. × 8 in. boards (blocks).
To lift and move the machine:

1. Move the machine's pallet as close as possible to the desired location with a pallet jack.
2. The machine is secured to the pallet with two screws in the base of each foot. Remove the screws from the pallet with an 8 mm wrench.

   Note: If you have a forklift, use it to lift and move the machine off of the pallet now. When finished, go to "Level the Machine" (page 42).

3. Verify that the top nut on each machine foot is loose.

   Note: The top nut is used to lock the height of the machine in place (which you'll do after you're done leveling the machine). The bottom nut raises or lowers the machine.

4. Raise the machine up about 1 in. by turning the lower nut on each machine foot with an adjustable wrench (provided in the tool bag).
   This raises the machine up to make room for the supports.

Figure 4-2: Turning the lower nut on the machine foot.

Tip! You can also use a 22 mm wrench, if you have it available.

5. Put two supports on the pallet so that they're approximately 6 in. from each end of the machine stand. Verify that there's enough room between the supports for the pallet jack.
6. Stack blocks under each end of the supports as shown in the following image.

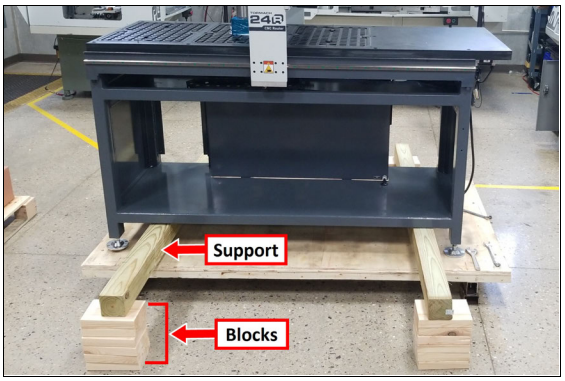


Figure 4-3: Boards arranged under the machine to prepare for pallet removal.

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.

7. Lower the machine with an adjustable wrench until the weight of the machine is completely held by the supports. Verify that the feet aren't touching the pallet.

8. Slowly remove the pallet from under the machine.

Figure 4-4: Pallet removed from the machine, which is now completely held by the boards.

9. Lift the machine off of the supports with a pallet jack. If your pallet jack doesn't lift high enough to move the machine, stack blocks on it. You must verify that the additional blocks are placed evenly on the pallet jack, and that they're beneath all four lifting points on the machine before attempting to raise the pallet jack.

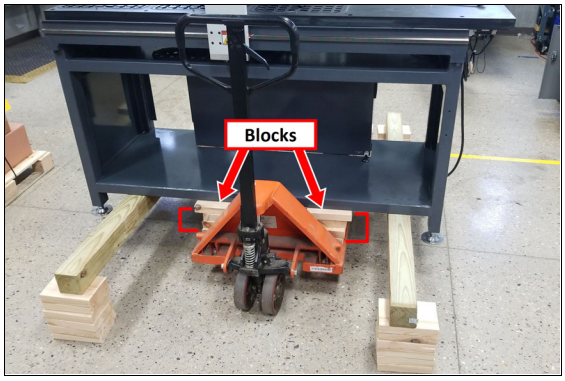


Figure 4-5: Lifting the machine from the boards with a pallet jack (and additional boards).

10. Once the weight of the machine is fully supported by the pallet jack, begin lowering the machine onto the floor:
    a. Remove two of the blocks from each end of the supports.
    b. Slowly lower the pallet jack until the weight of the machine is fully supported by the supports.
    c. Remove two of the blocks from the pallet jack.
    d. Lift the machine off of the supports with the pallet jack.
11. Repeat Step 10 until the weight of the machine is entirely on the floor.

4.5 LEVEL THE MACHINE

Tools and Items Required

- 24 mm wrench
- Adjustable wrench
- Carpenter's level

1. Put a carpenter's level on the machine table. Verify that the level is flat on the table, and isn't on the vacuum table gaskets.

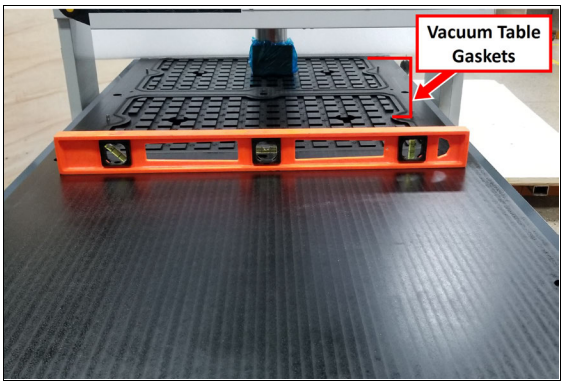


Figure 4-6: Carpenter's level on the machine table.

2. Raise or lower each foot by turning the lower nut with an adjustable wrench to level the machine in the X and Y directions.
3. Examine all four feet and verify that each foot touches the floor.
4. Tighten the top nut (the jam nut) on each foot with a 24 mm wrench.

4.6 INSTALL THE STAND END PANEL

Tools and Items Required

- 3 mm hex wrench

1. Find the water chiller and the stand end panel that you set aside in "Unpack the Machine Crate" (page 39). Then, remove and discard the plastic wrap that secures the stand end panel to the water chiller.
2. We've preinstalled the hardware for the stand end panel onto the front right end of the machine stand. Remove all four screws with a 3 mm hex wrench (provided in the tool bag).

Figure 4-7: Stand end panel hardware installed on the machine stand.

3. Install the stand end panel onto the machine stand with the four screws from Step 2 and a 3 mm hex wrench.

Figure 4-8: Installing the stand end panel on the machine stand.

4.7 INSTALL THE CONTROLLER ARM

Tools and Items Required

- #5 drill bit
- 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)
- Drill
- Phillips screwdriver
- Pry bar
- Tape

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.

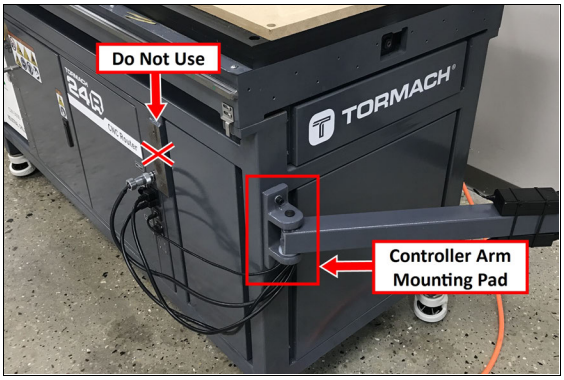


Figure 4-9: Controller Arm mounting pad.

WARNING! Crush Hazard: Only install the Controller Arm on the mounting pad at the front end of the machine. If there's a mounting pad next to the electrical cabinet on the machine stand, don't use it. If you do, there's a risk of entrapment between the Controller Arm and the machine's moving parts.

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.

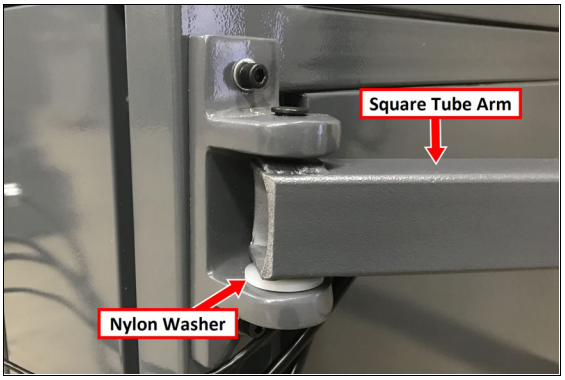


Figure 4-10: White nylon washer on the square tube arm.

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.

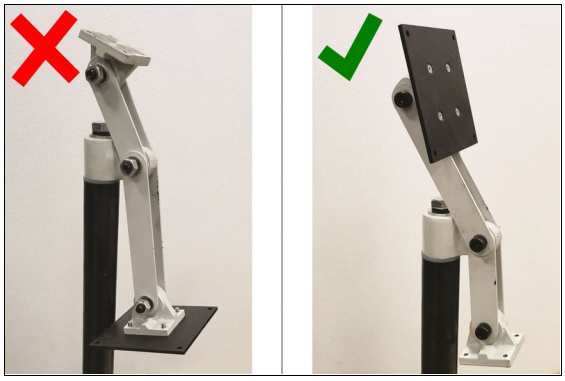


Figure 4-11: Incorrect and correct orientations of the monitor bracket on the Controller Arm.

> **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 4-12: 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. Find the operator box drill template (provided in the machine owner's kit). Put the template on the operator box, and verify that the holes on the operator box align with the holes on the template. If they don't, trace the correct hole pattern on the template.
11. Tape the template to the keyboard tray as shown in the following image. This indicates the location to mount the operator box, which you'll do later in this procedure.

Figure 4-13: Template taped to the keyboard tray.

12. Drill the four holes through the template and into the keyboard tray with a drill and a #5 drill bit.
13. Remove the template from the keyboard tray, and then discard it.
14. 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.

15. Find the operator box (in the tool bag), and mount it to the bottom of the keyboard table with four M5 × 25 mm screws and four M5 nuts (provided in the machine owner's kit).

Figure 4-14: Operator box installed on the keyboard tray.

16. Route the loose end of the cable from the operator box down the monitor post, through the openings in the square tube arm, and toward the electrical cabinet.
17. Connect the cable from the operator box to the Emergency Stop Input port on the front right end of the electrical cabinet. Tighten the locking collar to secure the cable.

Figure 4-15: Operator box cable connected to the Emergency Stop Input port.

18. Attach four wire tie mounts to the monitor post with four 4 mm flat head machine screws and a Phillips screwdriver.

4.8 INSTALL THE CONTROLLER

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

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

4.8.1 Install the PathPilot Operator Console

Tools and Items Required

- 16 mm wrench
- Metric hex wrench set
- Phillips screwdriver

1. Put the operator console against the monitor mounting plate and align the holes. Attach the operator console and monitor mounting plate together with four M4 × 12

mm socket head cap screws (provided with the operator console).

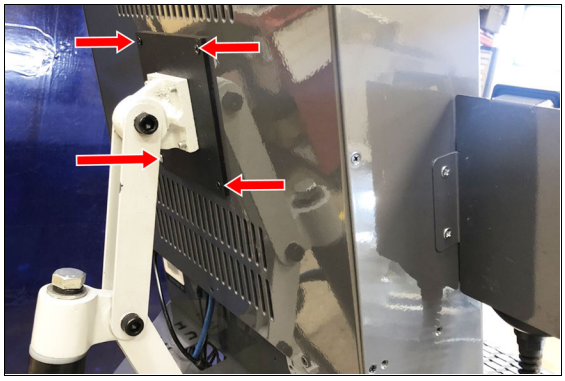


Figure 4-16: Operator console attached to the monitor mounting plate.

2. Attach the keyboard tray to the lower controller arm mount with an 8 mm hex wrench.

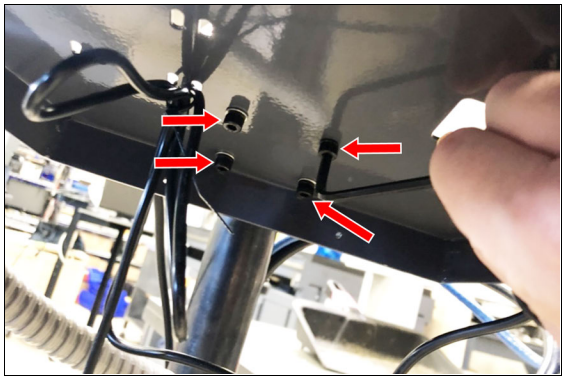


Figure 4-17: Attaching the keyboard tray to the lower controller arm mount (from below).

3. Adjust the operator console and the keyboard tray so that the two holes on the underside of the operator console line up with the holes on the keyboard tray.
4. Attach the keyboard tray to the operator console with two M3 Phillips screws (provided in the controller box) and a Phillips screwdriver.

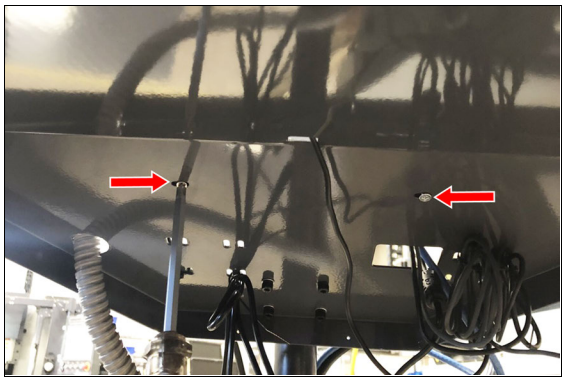


Figure 4-18: Attaching the keyboard tray to the operator console (from below).

5. Put the operator console's power supply into the power supply bracket (provided in the operator console box), and attach the assembly to the underside of the keyboard tray with M3 Phillips screws and a Phillips screwdriver.

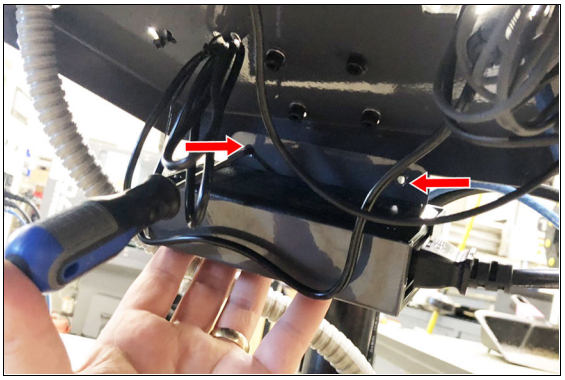


Figure 4-19: Attaching the operator console's power supply and power supply bracket to the keyboard tray (from below).

6. Connect the 12 ft power cable to the power supply.
7. Use the three pivot bolts on the controller arm monitor bracket to adjust the position of the operator console and the keyboard tray to your desired angle with a 3 mm hex wrench and 16 mm hex wrench.
8. If you have any of the following optional USB accessories, connect them to any **USB** port on the operator console:
   - Keyboard
   - Mouse
9. Connect the WiFi dongle to any **USB** port on the operator console.
10. Connect the Ethernet cable to the **Ethernet** port on the operator console.

11. Connect the barrel end of the power supply cable to the **Power Supply** port on the operator console.

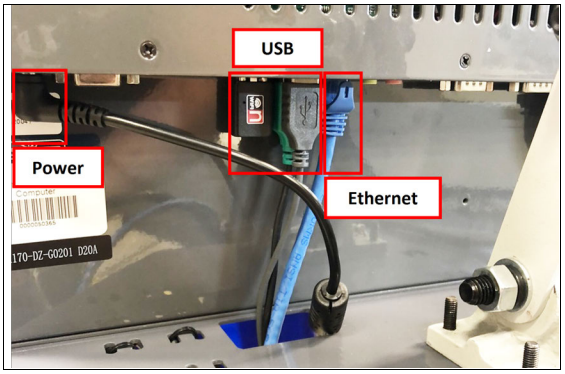


Figure 4-20: USB accessories connected.

12. Route the loose ends of the USB, Ethernet, and power supply cables through the square hole in the keyboard tray. Then, use the cable tie holes to secure the loose power supply and USB cables.

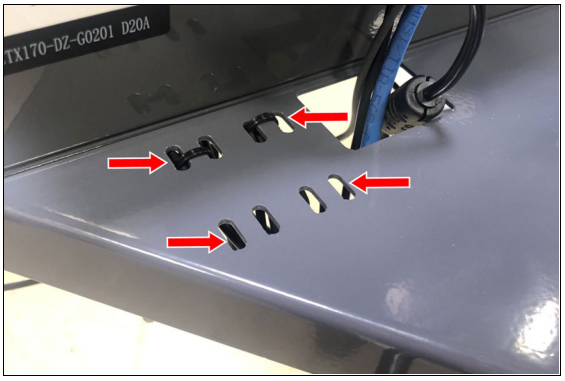


Figure 4-21: Cable tie holes.

> **Tip!** If you're using a mouse, we recommend leaving some slack for it to move freely.

13. Connect the jog pendant cable and the Emergency Stop cable to the operator console.

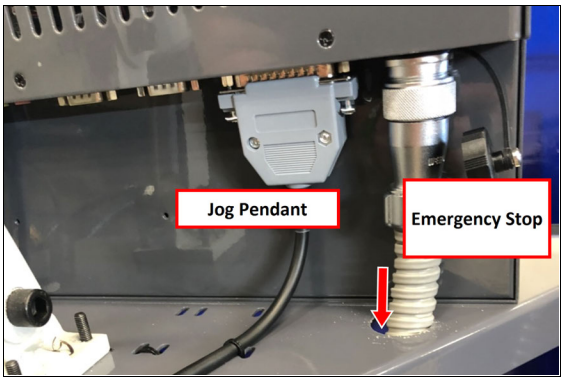


Figure 4-22: Jog pendant (left) and Emergency Stop (right) cables connected.

14. Connect the cable from the operator box to the Emergency Stop Input port on the front right end of the electrical cabinet. Tighten the locking collar to secure the cable.

Figure 4-23: Operator box cable connected to the Emergency Stop Input port.

15. Route the loose end of the operator console's 12 ft power cable, and the Ethernet cable down the controller arm. Then, route the cables through the slots in the square tube arm that's connected to the machine stand.
16. On the right side of the machine, connect the loose ends of the cables as follows:
    a. Connect the operator console's power cable to any of the **Accessory** power outlets.
    b. Connect the Ethernet cable to the **Controller Communications** port.
17. Secure the cables to the wire tie mounts that you installed on the round monitor post with four 4 in. cable ties.

4.8.2 Install the Monitor

Tools and Items Required

- 3 mm hex wrench
- 8 mm hex wrench
- 16 mm wrench
- PathPilot Controller VESA Mount (PN 50382)

The PathPilot controller mount allows you to install the PathPilot controller behind the monitor (which is attached to the Controller Arm).

> **Note:** If you're using a Touch Screen Kit (PN 35575), you must first remove the stock mounting bracket from the back of the monitor.

1. Put the PathPilot Controller VESA Mount (PN 50382) against the monitor mounting plate. Then, put the monitor on the other side of the PathPilot controller mount, and align the holes on the three components.
2. Attach the monitor, PathPilot Controller VESA Mount, and monitor mounting plate together with four M4 × 12 mm socket head cap screws (provided with the PathPilot Controller VESA Mount).

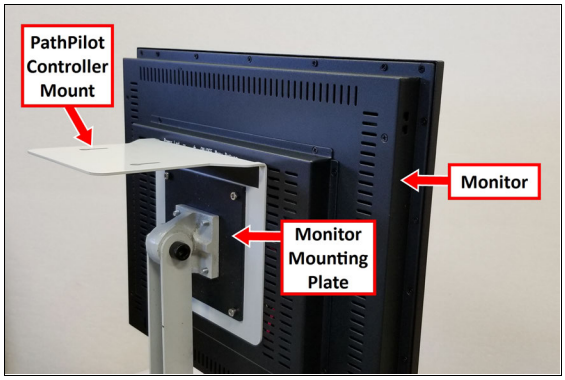


Figure 4-24: PathPilot controller mount attached to the back of the monitor.

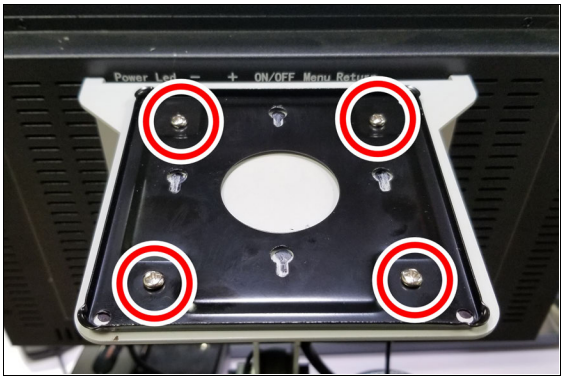
3. Adjust the position of the monitor and the keyboard tray with an 8 mm hex wrench and a 16 mm wrench. Once complete, securely tighten the pivot screws.

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 PathPilot controller.
6. Connect the loose end of the video cable to the monitor.

7. Connect the monitor's power cord. Depending on the type of monitor you have, do one of the following:
   - **Standard LCD Monitor (PN 30615)**
     a. Connect two of the **Controller/Monitor** cables (provided in the machine owner's kit) together. Then, connect one end of the cable assembly into the monitor.
     b. Route the loose end of the cable assembly down the monitor post, through the square tube arm, and toward the electrical cabinet.
     c. Connect the cable assembly into one of the Accessory Power Ports on the front right end of the electrical cabinet.

Figure 4-25: Connecting the monitor cable to the Accessory Power Port.

   - **Touch Screen Kit (PN 35575)**
     a. Connect the monitor's power supply into the monitor.
     b. Route the power supply down the monitor post.
     c. Connect one end of one **Controller/Monitor** cable (provided in the machine owner's kit) to the loose end of the monitor's power supply.
     d. Route the loose end of the **Controller/Monitor** cable through the square tube arm and toward the electrical cabinet.
     e. Connect the loose end of the **Controller/Monitor** cable into one of the Accessory Power Ports on the front right end of the electrical cabinet.
     f. Attach the power supply to the monitor post with one cable tie (provided in the machine owner's kit).
8. Connect the PathPilot controller's power supply to the PathPilot controller.
9. Connect the loose end of the power supply to one of the **Controller/Monitor** cables provided.
10. Route the power cable down the monitor post, through the square tube arm, and toward the electrical cabinet.
11. Connect the loose end of the **Controller/Monitor** cable into one of the Accessory Power Ports on the front right end of the electrical cabinet.
12. Attach the PathPilot controller and monitor power supplies to the square tube arm with cable ties (provided in the machine owner's kit).

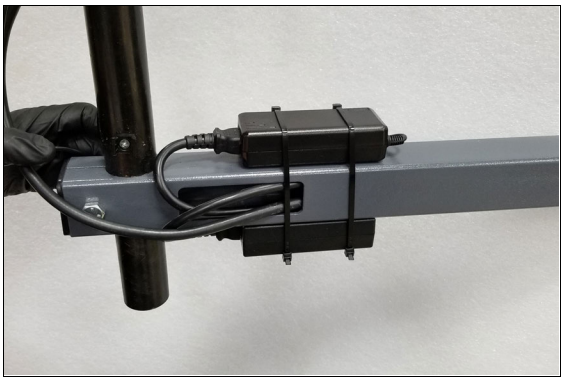


Figure 4-26: Power supply attached to the square tube arm.

13. Find the Ethernet cable (provided in the machine owner's kit), and then connect it to the Controller Communications outlet on the front right end of the electrical cabinet.
14. Route the loose end of the Ethernet cable toward the PathPilot controller, and then connect it to the PathPilot controller.
15. Secure the operator box cable, Ethernet cable, and power supply cables to the Controller Arm with four wire tie mounts and four cable ties.

4.9 MAKE WATER CHILLER CONNECTIONS

Tools and Items Required

- Distilled water, 2-1/4 gal

1. Find the water chiller that you set aside in "Unpack the Machine Crate" (page 39). Then, remove the components from the box the water chiller is shipped in. Set the two cables aside.
2. Put the water chiller into the machine stand.
3. Find the two preinstalled water lines in the machine stand. Then, route both toward the water chiller.
4. Connect the water lines to the water chiller:
   a. Put the clear water line into the Inlet port.
   b. Put the black water line into the Outlet port.
5. Find the water chiller alarm cable (that you set aside in Step 1). Then, connect one end to the back of the water chiller.

Figure 4-27: Water chiller connections.

6. Route the loose end of the water chiller alarm cable toward the electrical cabinet, and connect it to the Chiller Alarm Input port on the side of the left end of the electrical cabinet.

Figure 4-28: Water chiller cable connected to the Chiller Alarm Input port.

7. Fill the water chiller with 2-1/4 gal of distilled water.
8. Find the water chiller's power cable (that you set aside in Step 1). Then, connect one end to the back of the water chiller.
9. Route the loose end of the power cable to a 115 Vac outlet, and connect it.
10. Turn on the water chiller and examine the clear water line to confirm that water is flowing.
11. Inspect the water chiller and water lines for leaks.

4.10 VERIFY THE INSTALLATION

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

4.10.1 Before You Begin

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

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 4-29: The Main Disconnect switch on the side of the machine's electrical cabinet.

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

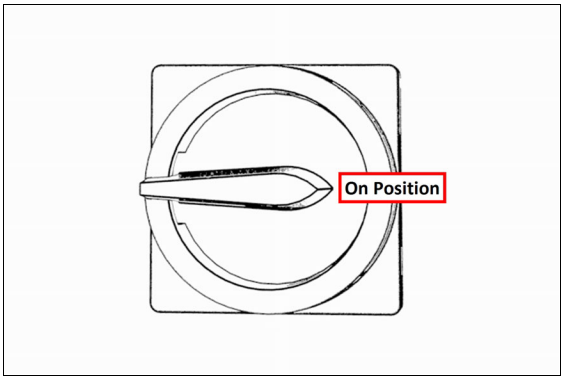


Figure 4-30: Example of the Main Disconnect switch in the On position.

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

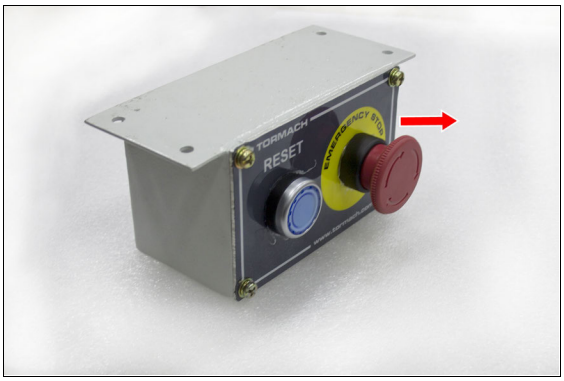


Figure 4-31: The Emergency Stop button on the operator box.

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

Figure 4-32: 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 4-33: Machine OK light on the Status tab.

12. Select **Reset**.

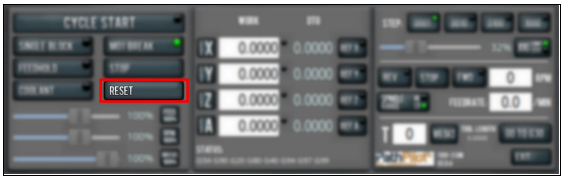


Figure 4-34: Reset button.

Power Off the Machine

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

Figure 4-35: 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**.

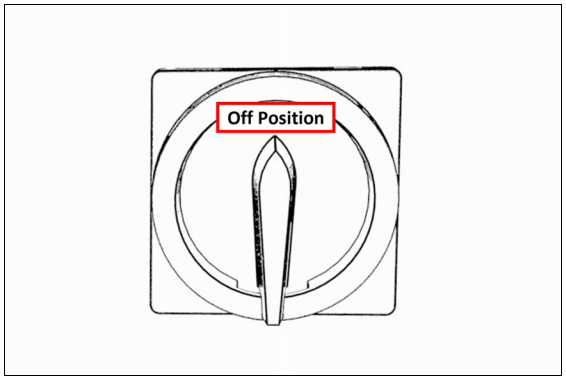


Figure 4-36: Example of the Main Disconnect switch in the Off position.

Mains power is disconnected from the machine.

4.10.2 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 4-37: X Limit, Y Limit, and Z Limit lights on the Status tab.

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

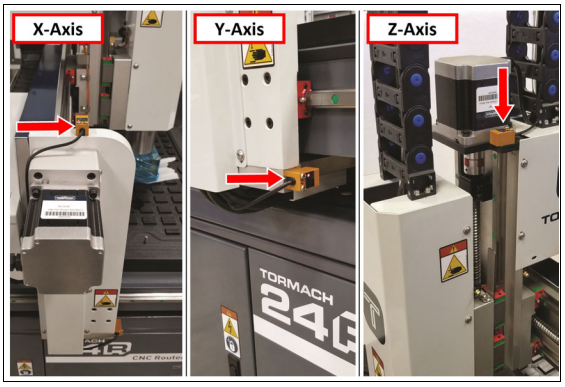


Figure 4-38: Machine limit switches.

4. Hold a piece of steel (like a screwdriver or a wrench) up to each limit switch.
   The red light on each limit switch is on until the steel is within sensing range, at which point the red light dims or turns off.
   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**.

4.10.3 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 4-39: 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 spindle moves right (X+), then left (X-).
   - Select the **Up Arrow** key and then the **Down Arrow** key.
     The gantry moves toward the back end of the table (Y+), then toward the front (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.

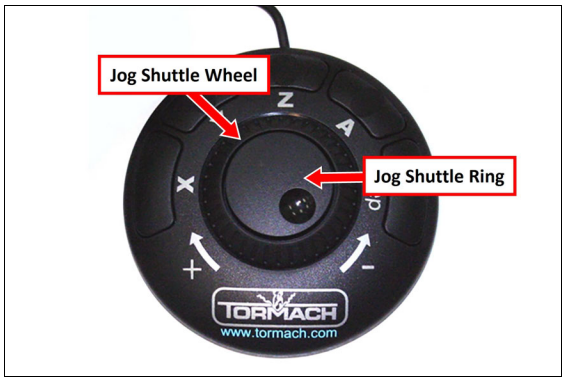


Figure 4-40: Functions on the optional Jog Shuttle.

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

Figure 4-41: Axis lights.

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

4.10.4 Verify Spindle Function

You must confirm that the spindle correctly operates.

1. Remove the collet and nut from the spindle, if installed.
2. If you haven't already done so, turn on the water chiller.
3. 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%**.

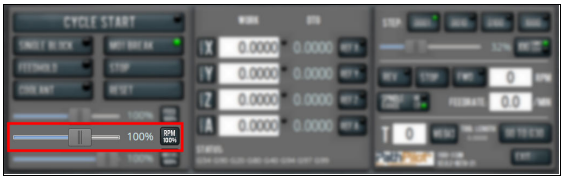


Figure 4-42: Spindle Override slider.

> **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 128).

4. From the PathPilot interface, in the **RPM** DRO field, type `10,000`. Then select the **Enter** key.
5. Select **FWD**.

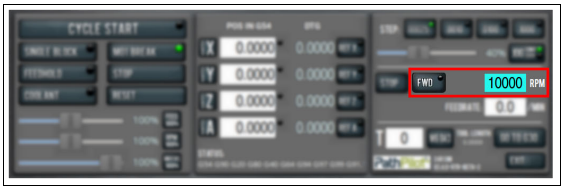


Figure 4-43: Spindle controls.

   The spindle rotates clockwise (viewed from above) at 10,000 rpm.
6. Select **STOP**.
   The spindle stops rotating.
7. In the **RPM** DRO field, type `11,000`. Then select the **Enter** key.
8. Select **FWD**.
   The spindle rotates clockwise (viewed from above) at 11,000 rpm.
9. Repeat the procedure in 1000 rpm intervals up to 24,000 rpm.

4.11 INSTALL THE AUTOMATIC TOOL CHANGER (OPTIONAL)

Complete the following steps in the order listed:

4.11.1 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.
- **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.

4.11.2 Required Tools

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

- An assistant to help you
- 3 mm hex wrench
- 4 mm hex wrench
- 6 mm hex wrench
- 14 mm wrench
- 16 mm wrench
- Flat-blade screwdriver, small
- Marker
- Phillips screwdriver
- Wood block

4.11.3 Remove the Existing Spindle (ER20)

1. Verify that the collet nut is installed and that there's no tooling in it.
2. Put a block of wood below the spindle on the machine table. Then, slowly jog the Z-axis down until the spindle is resting on the block of wood.

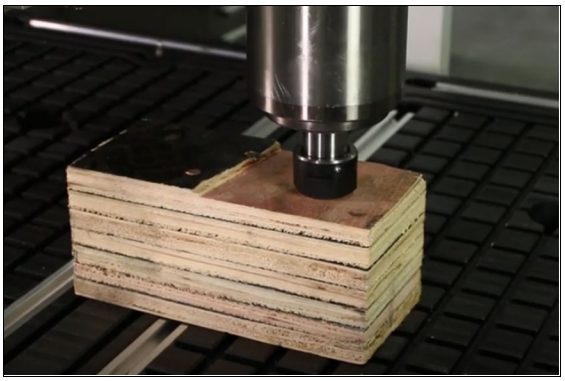


Figure 4-44: Wood block to support the spindle.

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.
4. Remove the six M5 button head cap screws that secure the front spindle cover with a 3 mm hex wrench. Set aside the screws and the cover.

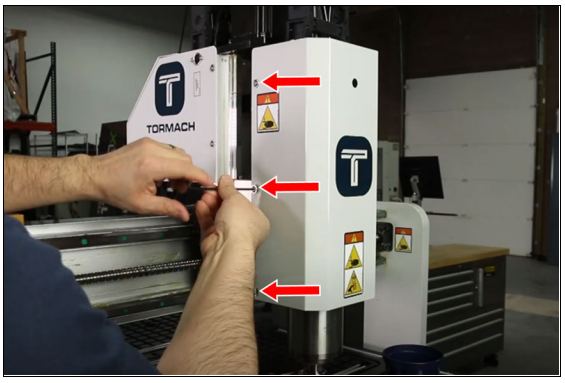


Figure 4-45: Removing the M5 screws that secure the front spindle cover.

5. Identify the spindle power connector and disconnect it.

Figure 4-46: Spindle power connector.

6. From the top of the spindle, disconnect the two water lines with a 14 mm wrench.

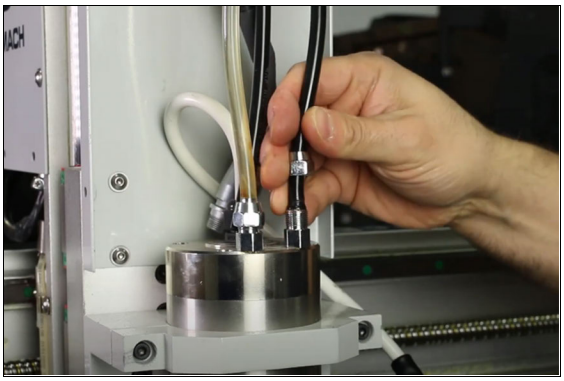


Figure 4-47: Two water lines on the existing spindle.

> **Note:** We recommend that you put a piece of tape or a black mark on the clear water line. There's another clear line involved in this procedure, so marking this line helps to prevent confusion.

7. If the water lines are difficult to remove from the fitting, cut them with a knife about 1/2 in. above the fitting.

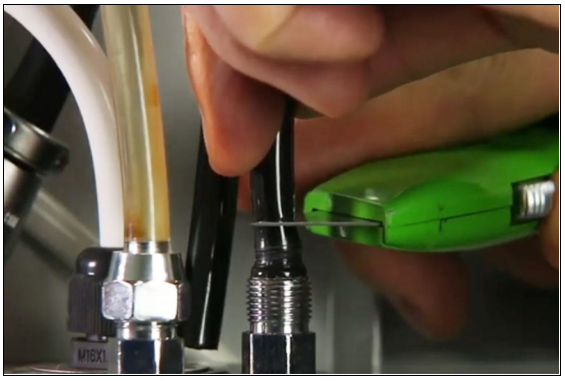


Figure 4-48: Cutting the water lines from the fitting.

8. Mark each of the spindle clamps, as shown in the following image, to indicate which is the top and which is the bottom. You'll use the marks later to correctly realign the spindle clamps to the spindle mount.

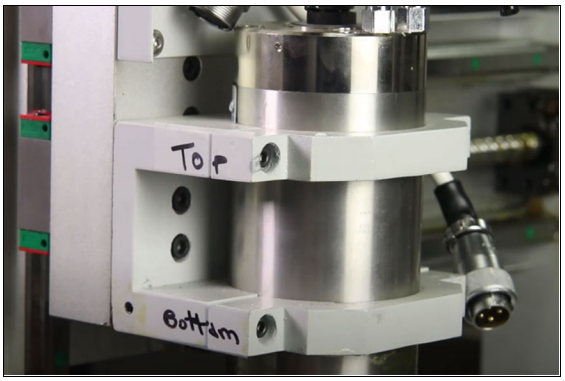


Figure 4-49: Spindle clamps marked to indicate the top and bottom.

9. Use one hand to support the spindle, and use your other hand to remove the four M5 socket head cap screws that secure the spindle clamps. Set aside the screws and the spindle clamps.
10. Remove the existing spindle (ER20) from the spindle mount.

4.11.4 Install the New Spindle (ISO20)

Before You Begin: A Note About Spindle Heights

You can adjust the installation height on the 24R spindle to fit your project. For example, you can install it lower to be able to machine thin parts with short tools or you can raise the spindle up to give yourself more clearance for thicker parts and long tooling.

As a good starting point, we recommending starting low and keeping the black portion of the spindle flush or slightly above the top clamp.

1. Put the ISO20 spindle onto wood blocks on the machine table, and then put the spindle into the spindle mount. Orient the spindle so that the coolant ports are pointing toward the front.

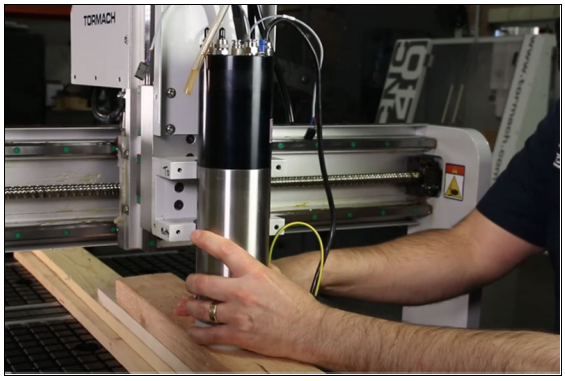


Figure 4-50: Putting the spindle into the spindle mount.

2. If necessary, use additional pieces of wood or cardboard to raise the spindle higher in the spindle mount. Don't mount the spindle too low — verify that both clamps are clamped on the main body (the silver section) of the spindle, and that the clamps are spaced evenly on each side.
3. Mount the ISO20 spindle with the spindle clamps and screws (that you set aside earlier) and a 4 mm hex wrench. Align the top and bottom mounts, as shown in the following image, using the marks that you made on the spindle mount before you removed the clamps.

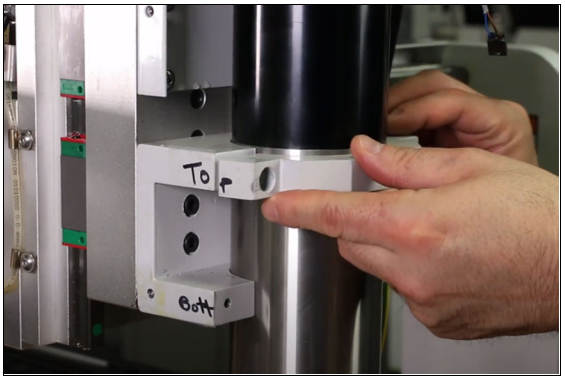


Figure 4-51: Mounting the ISO20 spindle.

> **Tip!** It may be useful to have an assistant help support the spindle while you're installing the clamps.

4. Remove the two shipping bolts from the top of the spindle.

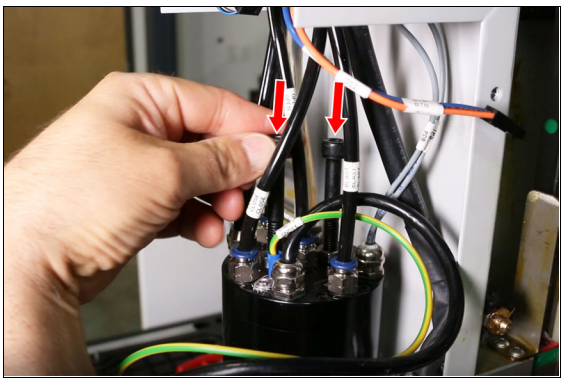


Figure 4-52: Shipping bolts installed on the top of the spindle.

5. Remove the cap from the coolant ports with a 14 mm wrench. Then connect the water lines to the fittings on the top of the spindle in the following order:
   - Connect the black line to the **Water Inlet**.
   - Connect the clear line to the **Water Outlet**.

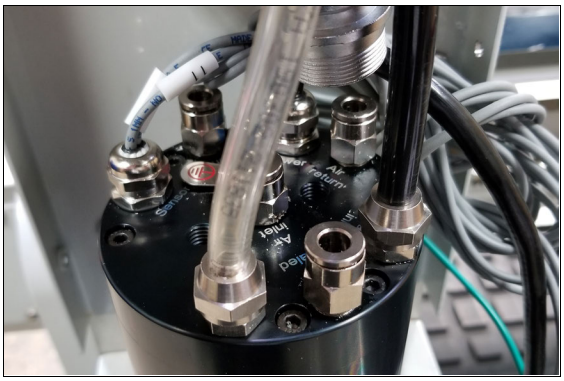


Figure 4-53: Water line connections.

6. Identify the spindle power connector on the spindle, and connect it to the machine's spindle power connector.

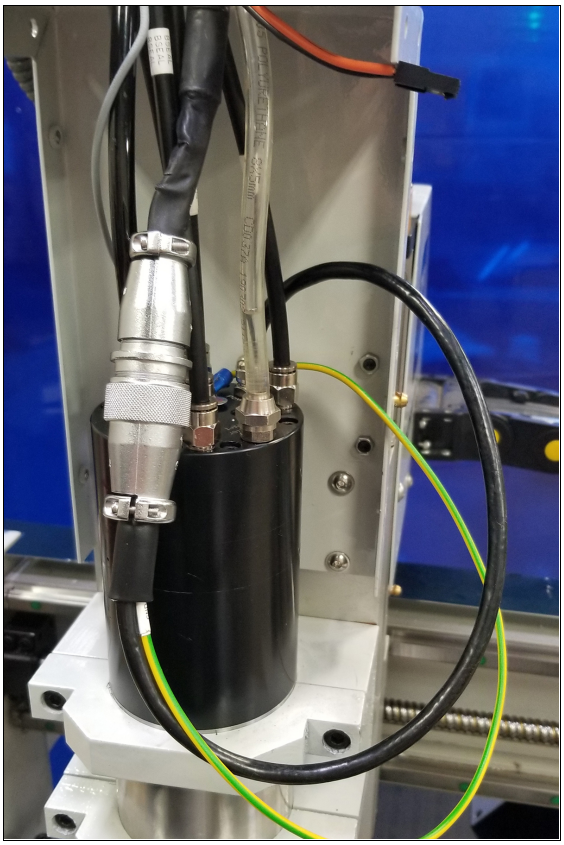


Figure 4-54: Spindle power connector.

7. Remove some pieces from the energy chain by gently prying them with a small, flat-blade screwdriver.

Figure 4-55: Removing pieces of the energy chain.

> **Tip!** We recommend leaving a few of the energy chain pieces installed to help keep the wires and tubes organized while you route the new lines.

8. Remove the eight M5 screws that secure the rear Z-axis access panel with a 3 mm hex wrench. Set aside the screws and the panel.

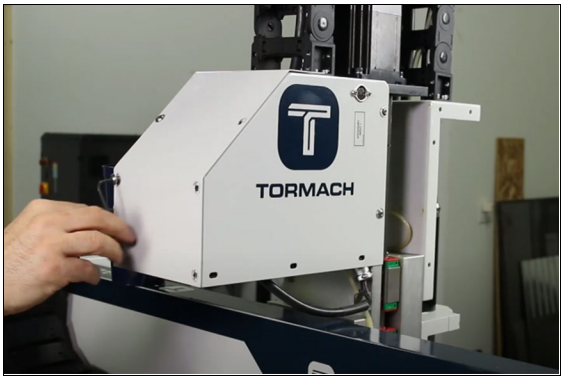


Figure 4-56: Rear Z-axis access panel.

9. Find the bag of hardware and wires that's provided with this kit. Then, identify the following items:
   - Power drawbar sensor cable (**PDB**), which contains wires 545-547.
   - Tool position sensor cable (**TPS**), which contains wires 548-550.
10. Connect the **PDB** and **TPS** cables to the coordinating cables on the spindle.
11. Route the following wires from through the energy chain and toward the rear Z-axis cover:
    - Power drawbar and tool position wires
    - Power drawbar open button wire

4.11.5 Rewire the ATC Cable

IMPORTANT! On earlier machines, the ATC cable wasn't installed on the inside of the electrical cabinet. Follow this procedure to verify this connection before installing the solenoid tray.

1. To determine if you need to connect your ATC cable, open the electrical cabinet and, on the terminal strip, find **wires 490, 491, and 492**.
   - **If the wires are connected, as shown in the following image**, skip this section and go to "Install the Solenoid Tray" (on the next page).

Figure 4-57: Wires 490, 491, and 492 connected.

   - **If the wires aren't connected, as shown in the following image**, proceed to the next step in this section.

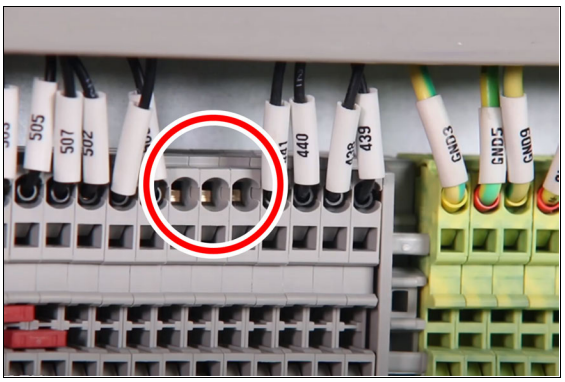


Figure 4-58: Wires 490, 491, and 492 not connected.

2. Remove the wire trough covers and set them aside.
3. In the electrical cabinet, locate the ATC cable — it's a black cable with six black wires and one green/yellow wire. The cable is in one of two places:
   - The left-most wire trough
   - The bottom wire trough
4. From the end of the ATC cable, measure 6 in. (15 cm) and make a mark.
5. Carefully strip away and remove the cable's main insulation all the way back to the mark with a knife or an insulation stripping tool.
6. Push the metal sleeve back so that it bunches up at the bottom, and carefully cut away at the material with wire cutters.
7. Trim away the extra plastic and paper from inside of the cable, and clean any talcum powder from the wires.
8. Strip 1/4 in. (6 mm) from the ends of the six black wires with a wire stripper.
9. In the rear Z-axis cover, find the round ATC connector on the ATC cable.
10. Use a multimeter to perform a continuity test between each pin on the ATC connector and each of the six black wires at the other end of the cable inside the electrical cabinet. Use the following table to identify each wire, and then apply a wire number label 2 in. from the end of each wire.

ATC Connector Pin	ATC Cable Wire
Pin 1	Wire 492
Pin 2	Wire 490
Pin 3	Wire 491
Pin 4	Wire 508

11. Trim the remaining three black wires and one green/yellow wire back to the main insulation with a pair of cutters. Because these wires aren't used for any connections, you can clean up any remaining metal sheathing and tape the wires back with electrical tape.
12. On the terminal strip, find the three open terminal blocks that you identified earlier.

13. Connect **wire 492** to the terminal block by inserting it into the open part of the terminal block across from **wire 487**.

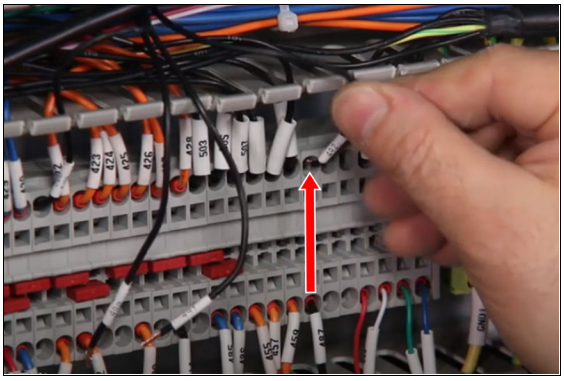


Figure 4-59: Connecting wire 492 to the terminal block.

14. Connect **wire 490** and **wire 491** into the open ports on the terminal block next to **wire 492**.

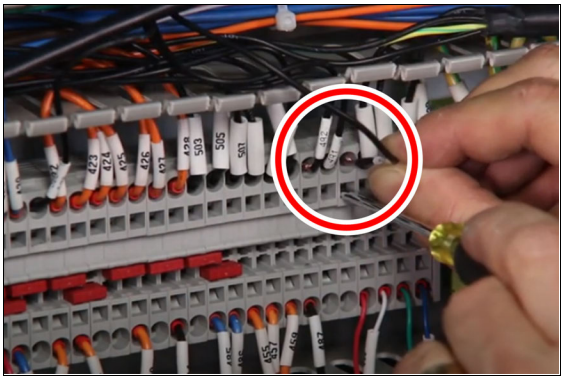


Figure 4-60: Connecting wire 490 and wire 491 to the terminal block.

15. Connect wire 508 to -24 Vdc by connecting it to one of the open terminals as shown below.

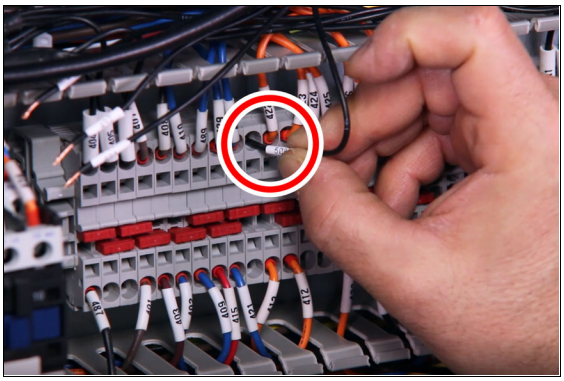


Figure 4-61: Connecting wire 508 to the terminal block.

4.11.6 Install the Solenoid Tray

1. Route the extra length of air supply line back through the energy chain and to the solenoid tray.
2. Find the solenoid tray provided with this kit, and then identify the ATC control board mounted in it.

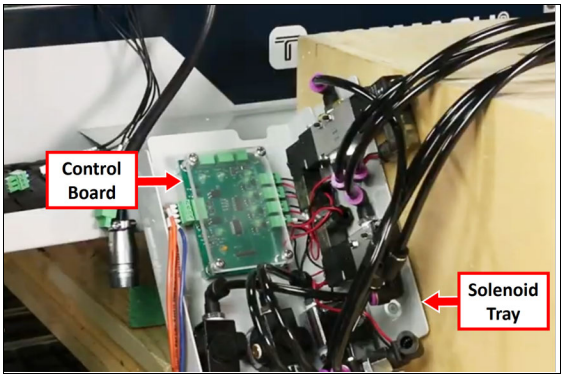


Figure 4-62: Control board in the solenoid tray.

3. Make the connections to the ATC control board as detailed in the following table.

Identify the...	Connect to...
BTN power drawbar button wires (from the Z-axis energy chain)	J6 connector
TPS wire cable (from the spindle)	J7 connector
PDB wire cable (from the spindle)	J8 connector

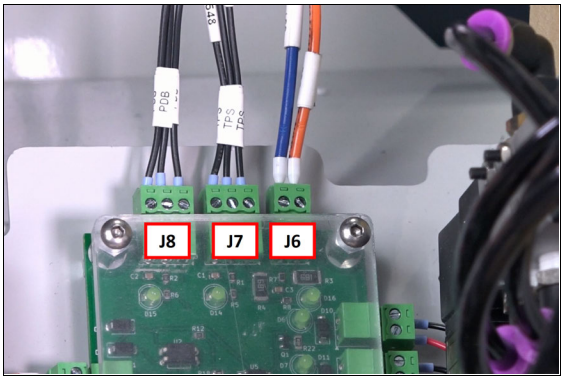


Figure 4-63: ATC control board connections.

4. Identify the pre-installed ATC cable in the rear Z-axis cover. Then, connect it to the ATC power connector on the ATC solenoid control assembly.

5. Lift the ATC solenoid control assembly up into the bottom of the rear Z-axis cover. Align the threaded holes on the side of the tray with the horizontal slots in the rear Z-axis cover.

> **Note:** Be careful to not pinch wires while lifting the tray into position.

Figure 4-64: Solenoid control assembly.

6. Find five M5 screws provided with this kit, and use them to secure the solenoid control assembly to the rear Z-axis cover.
7. Identify the pre-installed 8 mm air hose in the rear Z-axis cover. Then, trim the length and connect it to the 8 mm push-to-connect fitting on the ATC solenoid control assembly.

> **Note:** You may need to pull the air line back from within the inside of the Z-axis energy chain.

8. Reinstall all of the energy chain links that you removed earlier in this procedure.

4.11.7 Connect the Filter-Regulator-Lubricator (FRL) to the Rear of the Machine

1. Remove the two 1/4 in. push-to-connect fittings on either side of the FRL with a 14 mm open socket wrench.

Figure 4-65: Preinstalled push-to-connect fittings on the FRL.

2. Install the two included 5/16 in. push-to-connect elbows to either side of the FRL with a 14 mm open socket wrench. Teflon tape is preinstalled on these elbows.

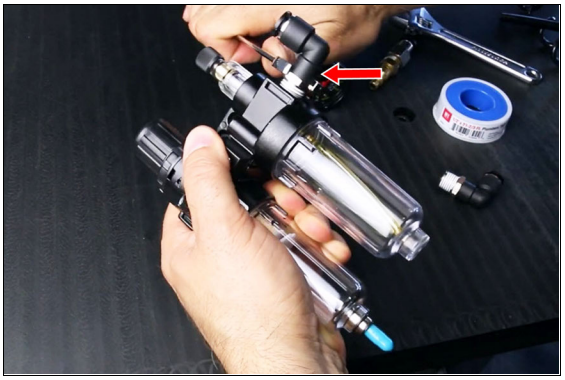


Figure 4-66: Installing the included push-to-connect elbows on the FRL.

3. Wrap Teflon tape onto the threads of the included dial. Then, install the dial on the FRL. Do not overtighten.

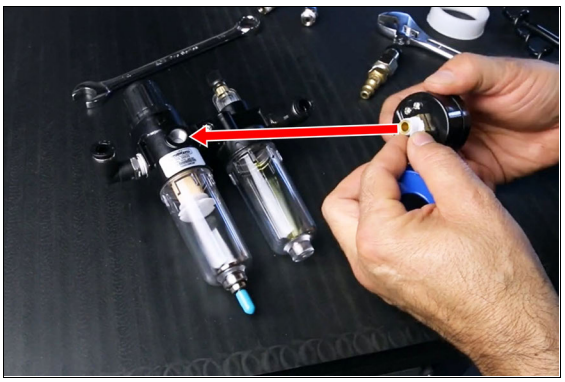


Figure 4-67: Preparing the dial for installation on the FRL.

4. On the rear of the machine, remove the bottom hex screw on the panel shown in the following image with a hex wrench.

Figure 4-68: Hex screw to remove for mounting the FRL.

5. Slide the included socket head cap screw into the top FRL bracket, and slide the spacer onto the backside of the screw. Then, secure the socket head cap screw to the machine with a 3 mm hex wrench.
6. Attach the air line going into the machine to the right push-to-connect elbow on the FRL.

Figure 4-69: Connecting the machine's air line to the FRL.

7. Connect the loose end of the 6 in. air line (with the air fitting) to the left push-to-connect elbow on the FRL.

> **IMPORTANT!** Don't connect the fitting to your shop's air supply yet. You'll do so later in this procedure.

4.11.8 Connect the Air Lines to the Spindle

1. Route the loose ends of the air lines from the solenoid panel assembly, through the Z-axis energy chain, and toward the spindle.
2. Identify the two air lines labeled **Lift** and **EXT**. Route the air lines toward the spindle and out the front of the Z-axis energy chain two links before the spindle cover. You'll connect the air lines later in this procedure.

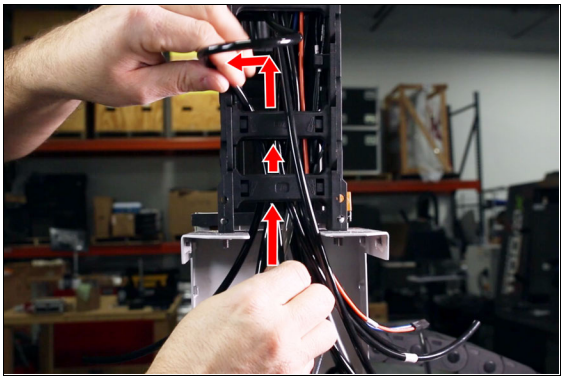


Figure 4-70: Pulling the dust shoe air lines through the energy chain.

3. Identify and connect the following air lines to the push-to-connect fittings on the top of the spindle.

Air Line	Fitting
Blast	Dust Removal
Open	Air Inlet
Seal	Air Sealed
Close	Air Return

Figure 4-71: Air line connections.

> **Tip!** If the air lines are too long, trim them to length.

4.11.9 Install the Power Drawbar Button

1. Unplug the power drawbar button at the connector near the spindle from the wires previously routed up through the Z-axis energy chain.
2. Put the power drawbar button into the hole on the spindle cover, and tighten the lock washer and nut onto the button.

Figure 4-72: Power drawbar button hole on the spindle cover.

> **Note:** Earlier machines (RA10001-RA10036) didn't include a hole for the power drawbar button. If you have one of these machines, use the new Spindle Cover (PN 39086) provided in this kit.

3. While holding the spindle cover up to the spindle head, identify the power drawbar button wires from the Z-axis energy chain, and plug them in to the power drawbar button.
4. Attach the spindle cover to the spindle head with the six M5 screws from earlier in this procedure and a 3 mm hex wrench.

4.11.10 Install the Lifting Dust Shoe

1. Verify that the top push-to-connect fitting on the dust shoe has the adjustment valve. If it's installed on the bottom, remove it with a wrench and switch it to the top location. Securely tighten both fittings.

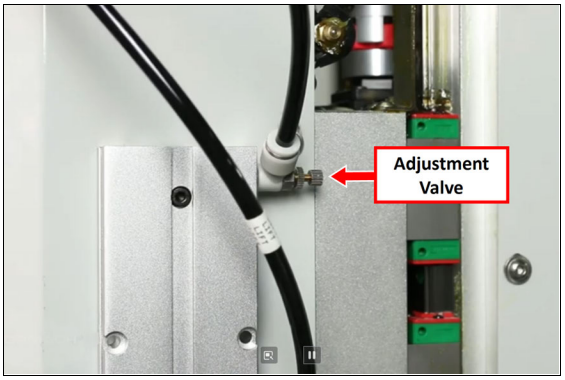


Figure 4-73: Adjustment valve on the top push-to-connect fitting of the dust shoe.

2. Slide the non-flanged end of the dust shoe onto the spindle. Then, align the center dust shoe holes on the spindle cover.

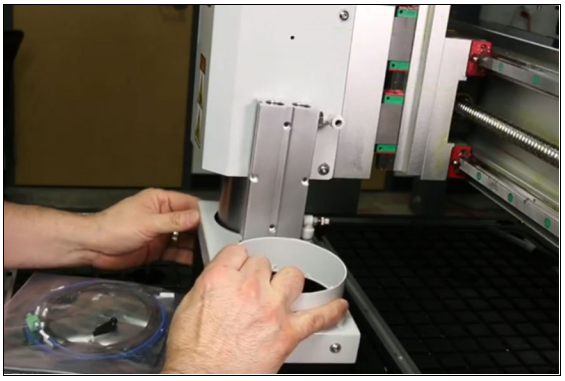


Figure 4-74: Sliding the dust shoe onto the spindle.

3. Mount the dust shoe to the spindle cover with the two socket head cap screws and a 3 mm hex wrench.

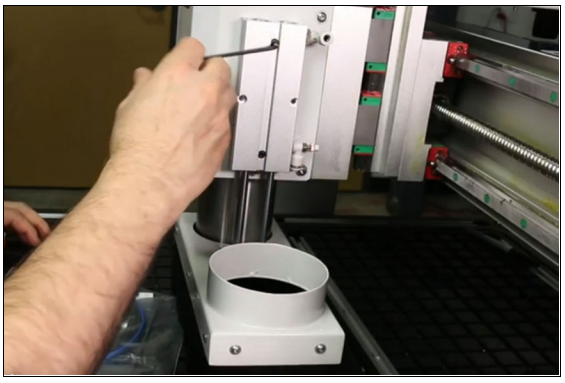


Figure 4-75: Mounting the dust shoe onto the spindle cover.

4. Install the air line labeled **LIFT** to the push-to-connect fitting into the lower port on the double rod cylinder (nearest to the dust shoe).

5. Install the air line labeled **EXT** to the push-to-connect fitting into the upper port on the double rod cylinder (furthest from the dust shoe).
6. Lift and lower the dust shoe, and observe the motion to determine if it rubs on the spindle. If it does, loosen the Phillips head screws a quarter-turn to adjust the position of the shoe until it's clear of the spindle. Then, re-tighten the Phillips head screws.

Figure 4-76: Adjusting the position of the dust shoe.

4.11.11 Install the ATC Communication Board

1. In the electrical cabinet, from the machine control board, remove the four screws securing the acrylic board shield with a 2.5 mm hex wrench. Set aside the shield and the screws.
2. Find the ATC communication board provided in this kit. Then, plug the black connector on the ATC communication board into the P1 auxiliary port on the machine control board.

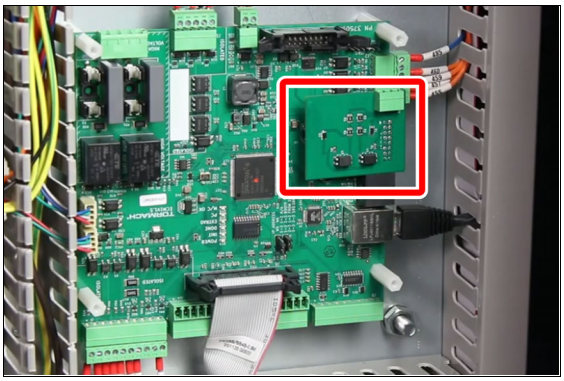


Figure 4-77: ATC communication board installed onto the machine control board.

3. Locate the wire harness for the ATC communication board with wires labeled **530** and **531**. Connect them as follows:

- Connect the loose end of **wire 530** to the open port of the terminal block connected to **wire 490**.
- Connect the loose end of **wire 531** to the open port of the terminal block connected to **wire 491**.

Figure 4-78: Wires 530 and 531 connected to the terminal block.

4. Connect the loose end of **wire 529** to the open port of the terminal block connected to **wire 508**.

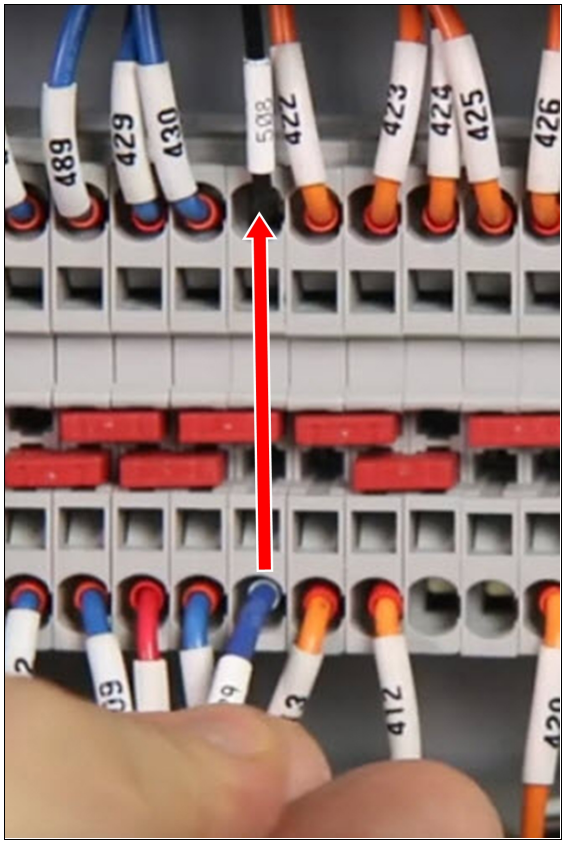


Figure 4-79: Wire 429 connected to the open port of wire 508.

5. Plug the green connector of the wire harness into the J2 connector on the ATC communication board.

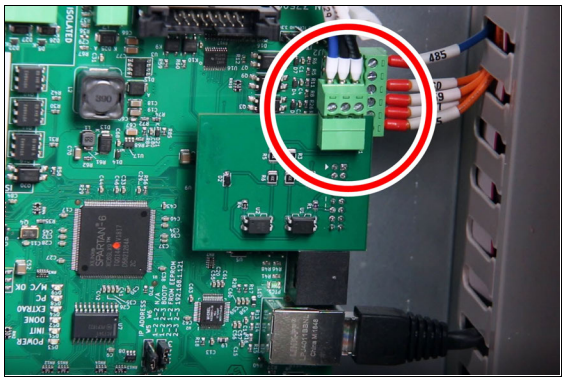


Figure 4-80: Connector J2 on the ATC communication board.

6. Re-install the acrylic board shield to the machine control board with the four screws that you set aside earlier.

> **Note:** If the spacers used previously no longer work, we've included additional plastic spacers in this kit for you to use.

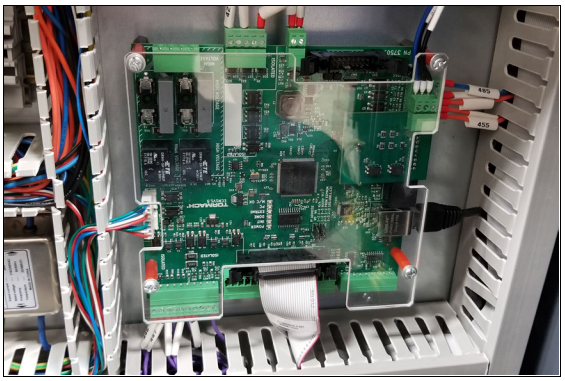


Figure 4-81: Shield installed on the machine control board.

7. Tuck all of the wires back into the wire troughs and replace all of the wire trough covers.

4.11.12 Install the ATC Rack

Prepare the Machine

1. On the machine table, near the back end (Y+) of the machine, locate the three M8 threaded holes on each side of the machine. You'll use these to mount the ATC rack. If you don't see the three threaded holes, you must remove the linear rail cover punch-outs.

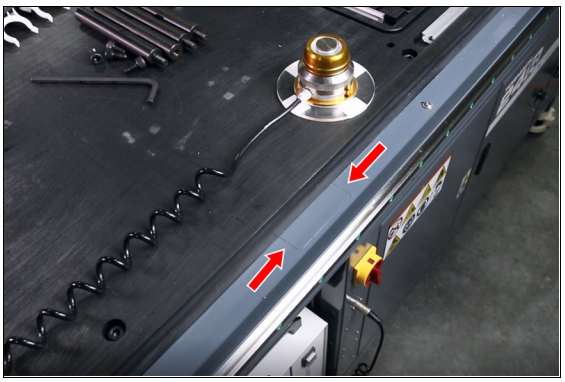


Figure 4-82: Linear rail cover punch-outs.

Remove Linear Rail Cover Punch-Outs

> **Note:** If your machine has punch-outs on the linear rail covers, you must remove them before you mount the ATC rack.

1. Remove the five M5 button head cap screws securing the left and right linear rail covers to the bed casting with a 3 mm hex wrench.
2. Put a short and a long wood block onto a secure work surface and align the first linear rail cover in the open space.
3. Support one of the linear covers with two wooden blocks, aligning the punch-out between the blocks.

Figure 4-83: Linear rail cover on two wooden blocks.

4. Break the tabs securing the punch-out to the linear rail cover with a punch and a hammer. Start with one of the tabs closest to the edge of the linear rail cover.

Figure 4-84: Using a punch to break the tab closest to the edge of the linear rail cover.

5. Break the remaining tabs one-by-one, working your way around the punch-out until all of the tabs are broken. Remove the punch-out.

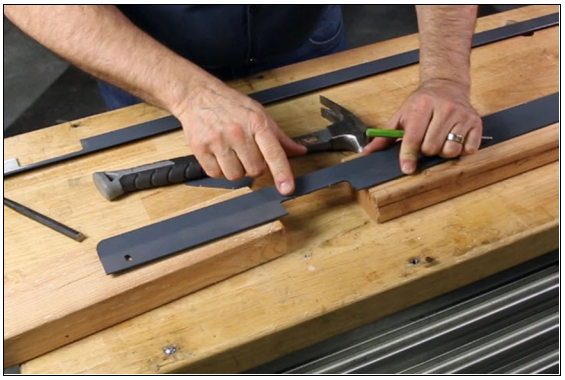


Figure 4-85: Linear rail cover with punch-out removed.

6. Repeat Steps 2 through 4 with the punch-out on the other linear rail cover.
7. Re-attach the linear rail covers to the bed of the machine with a 3 mm hex wrench and the five M5 button head cap screws that you set aside in Step 1.

Mount the ATC Rack

1. Find the ATC rack provided with this kit. Then, remove the four M8 bolts securing the standoffs to the bottom of the ATC rack with a 6 mm hex wrench and a 16 mm wrench. Set aside the M8 bolts.
2. Identify the two sets of three holes on either side of the machine table. You'll install the ATC rack's two standoffs into two of the holes (the hole that's furthest to the left is unused and remains open).

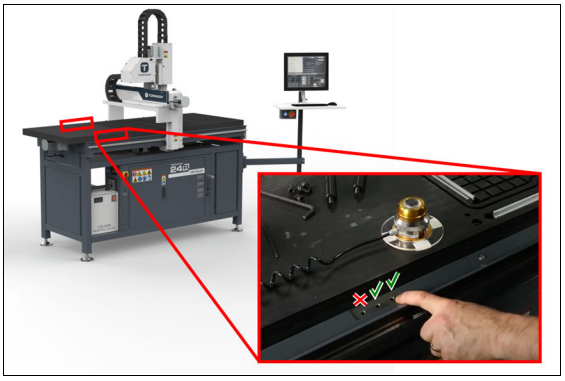


Figure 4-86: ATC rack standoff holes.

3. Install the standoffs into the two holes with a 16 mm wrench.

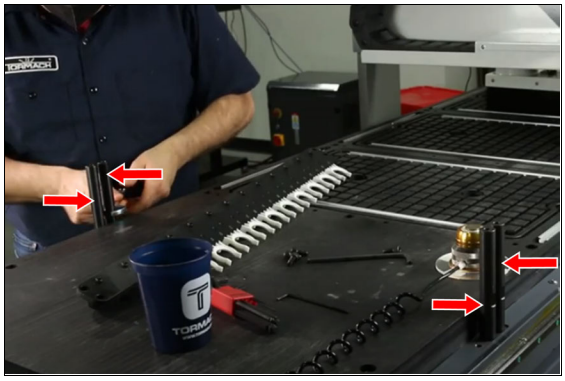


Figure 4-87: Installing the standoffs onto the machine.

4. Turn the rack so that the mounting screws for the tool forks are on the bottom of the rack, and then mount the ATC rack to the top of the standoffs with the four M8 bolts that you set aside earlier.

Figure 4-88: Installing the rack onto the standoffs.

4.11.13 Inspect the ATC Control Board

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.
2. If you haven't yet done so, you must update your controller to at least version 2.9.0 of PathPilot. From the PathPilot interface, on the **Status** tab, select **Update**.
3. Once PathPilot has been updated, from the **Settings** tab, select **Rack Tool Changer**.
   The **Rack ATC** tab displays next to the **Status** tab.
4. In the rear Z-axis cover, on the ATC control board, inspect the Power and Status LED lights. Confirm that they're illuminated as detailed in the following table.

LED	Light
Power (green)	On
Status (amber)	Off

4.11.14 Adjust the ATC Air Pressure Settings

The ATC has three air pressure control settings that you must adjust before operation.

Pressure Control Settings Overview

The three air pressure control settings are:

1. Spindle Nose Seal and Dust Shoe Extend Pressure Regulator (closest to the operator side of the machine (X-))
2. Dust Shoe Lift Pressure Regulator (furthest from the operator side of the machine)
3. Dust Shoe Lift Speed Control Valve

The **Spindle Nose Seal and Dust Shoe Extend Pressure Regulator** has two functions:

- The ISO20 spindle has a positive pressure air seal around the spindle nose. The constant flow of air from the spindle nose keeps dust out of the spindle bearings during operation. The pressure regulator controls the flow rate of air that is purged from the spindle nose.
- This pressure regulator also adjusts the downward force applied to the lifting dust shoe.

Both the spindle nose air seal and the downward force on the lifting dust shoe require the same amount of air pressure. The downward force on the lifting dust shoe should be enough to fully extend the dust shoe but not enough to fold the bristles in half when lifting the dust shoe with both hands.

The **Dust Shoe Lift Pressure Regulator** controls the upward force applied to the lifting dust shoe when in the up position. The pressure should be set such that the dust shoe fully lifts when commanded and the dust shoe can still be pushed downward with two fingers.

The Dust Shoe Lift Pressure Regulator should be adjusted after adjusting the Spindle Nose Seal and Dust Shoe Extend Pressure regulator.

The **Dust Shoe Lift Speed Control Valve** fitting is a one way flow control valve and it controls how quickly the dust shoe moves upward when it is lifted. This valve should be open

when adjusting the Spindle Nose Air Seal and Dust Shoe Extend Pressure Regulator and then fine tuned after setting the pressure on the Dust Shoe Lift Pressure Regulator.

Adjust the Spindle Nose Air Seal and Dust Shoe Extend Pressure Regulator

1. At the back of the machine, connect the air line from the air compressor to the FRL's air fitting inlet that you connected earlier. Verify that the air compressor is set between 90 psi and 120 psi.

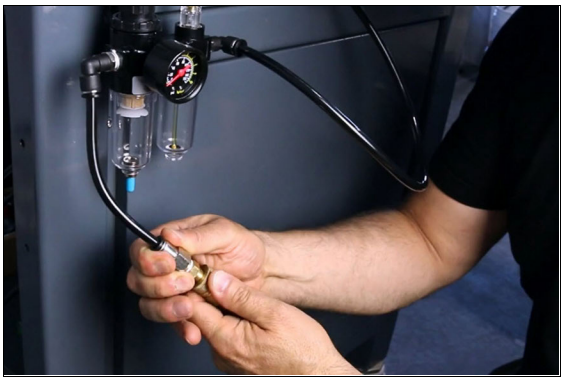


Figure 4-89: Connecting the air compressor's air line to the FRL.

2. Identify the dust shoe lift speed control valve on the top of the lifting dust shoe cylinder. Loosen the locking nut. Then open the valve by turning the adjustment screw counterclockwise 1-3 full turns.

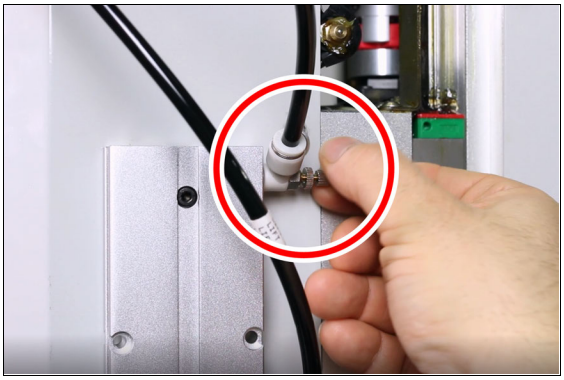
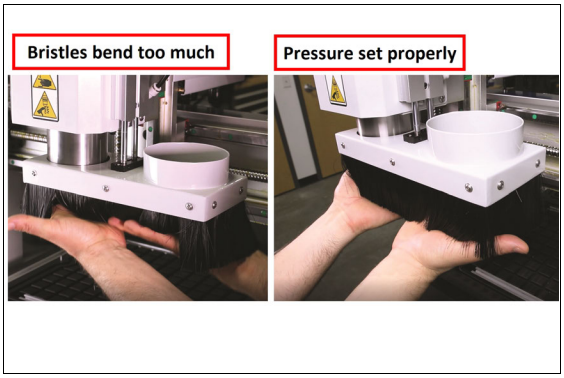


Figure 4-90: Loosening the dust shoe lift speed control valve.

3. On the bottom of the ATC solenoid control panel, identify the spindle nose air seal and dust shoe extend pressure regulator, and pull down to unlock the pressure regulator.

Figure 4-91: Unlocking the dust shoe extend pressure regulator.

4. Turn the knob clockwise to increase the air pressure until you begin to hear air coming from the air seal around the nose of the spindle.
5. Place the palms of both hands below the bristles of the lifting dust shoe and lift the dust shoe upward. Then release the lifting dust shoe and allow it to extend.
   a. If the lifting dust shoe does not fully extend, turn the air pressure regulator clockwise to increase the pressure.
   b. If the bristles on the dust shoe bend too much when lifting the dust shoe with both hands, turn the pressure regulator counterclockwise to decrease the pressure.



6. Once the pressure is set properly, push the knob back up to lock the pressure regulator.

Adjust the Dust Shoe Lift Pressure Regulator

1. From the PathPilot interface, select **Lift/Lower Dust Shoe**.

Figure 4-92: Dust Shoe button.

2. On the bottom of the ATC solenoid control panel, identify the dust shoe lift pressure regulator, and pull down to unlock the pressure regulator.

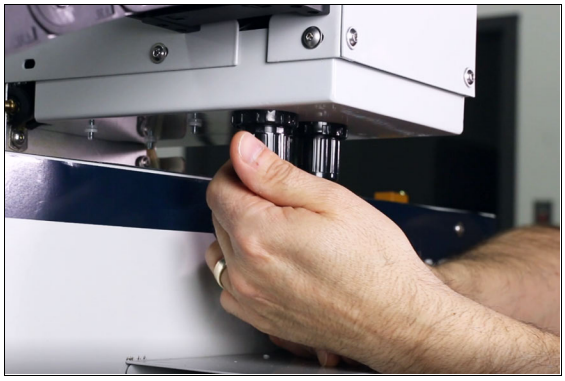


Figure 4-93: Unlocking the dust shoe lift pressure regulator.

3. Turn the knob clockwise to increase the lifting pressure until the dust shoe lifts all the way up.
4. Using two fingers, push the lifting dust shoe downward.

Figure 4-94: Pressing down on the dust shoe.

5. If you can't push the lifting dust shoe downward with two fingers, turn the pressure regulator counterclockwise to decrease the pressure.
6. From the PathPilot interface, select **Lift/Lower Dust Shoe**. The dust shoe goes back down.

Adjust the Dust Shoe Lift Speed Control Valve

1. From the PathPilot interface, select **Lift/Lower Dust Shoe** to lift the dust shoe. Observe the speed of how quickly the dust shoe lifts.
2. Select **Lift/Lower Dust Shoe Button** to lower the dust shoe.
3. On the top of the dust shoe lifting cylinder, identify the dust shoe lift speed control valve.

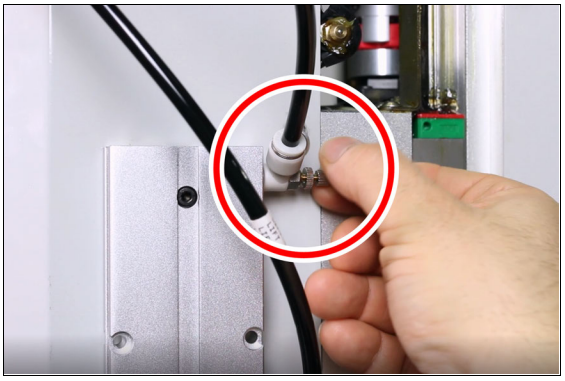


Figure 4-95: Loosening the dust shoe lift speed control valve.

4. Adjust the dust shoe lifting speed as follows:
   a. Rotate the adjustment screw clockwise to decrease the speed.
   b. Rotate the adjustment screw counterclockwise to increase the speed.
5. Repeat Steps 1 through 4 until the dust shoe lifts and lowers at roughly the same speed.

4.11.15 Verify the Power Drawbar Function

1. Identify the PDB button on the front of the spindle cover, and press and hold the power drawbar button.
   The power drawbar valve opens, and the power drawbar opens inside of the spindle.
   19:52
2. Insert an ISO20 tool holder into the spindle and release the power drawbar button.
   The drawbar closes and locks the tool into the spindle.

> **Note:** The power drawbar button does not lock the PDB in the open position. The PDB closes when the button is released.

3. While holding the tool in the spindle, select the **Collet** button on the **Rack ATC** tab in the PathPilot interface. The drawbar opens, releasing the tool from the spindle, and remains in the open position.

> **Note:** The collet button in PathPilot opens the power drawbar and locks it in the open position until either the collet button is pressed again or the PDB button on the front of the spindle is pressed and released.

4. Remove the tool from the spindle. Then, select **Collet**. The drawbar closes.
5. Select **Collet** to lock the drawbar in the open position. Then, select **Air Blast**.
   Air purges from the center of the spindle for about one second and then turns off.

> **Note:** The **Blast** button is used to test the air blast from the center of the spindle. The air blast is used to clear chips, dust and debris from the tool shanks when the machine performs an Automatic Tool Change.

4.11.16 Verify the Spindle Direction

> ***NOTICE!*** You must verify the spindle direction before operating the machine. If you don't, you could operate the spindle in the reverse direction, which could damage the spindle.

1. Remove the collet nut from an ISO20 tool holder and put a piece of tape onto the side of the tool holder. Draw a vertical line onto the tape. Then install the tool holder into the spindle.

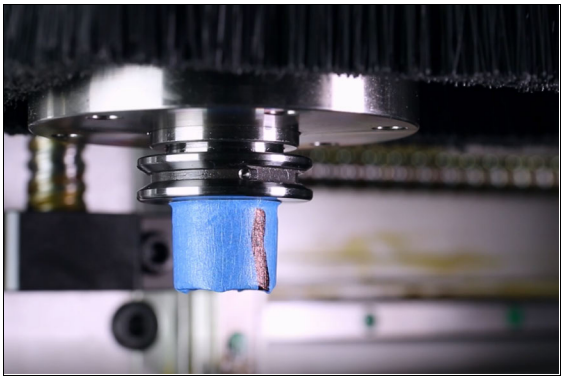


Figure 4-96: Tape and line indicator installed into the spindle.

2. From the PathPilot interface, on the **Main** tab, in the **RPM** DRO field, type `10,000`. Then select the **Enter** key.
3. While observing the spindle, select **Fwd**, and then select **Stop**.
   The spindle turns on, rotates counterclockwise, and turns off.

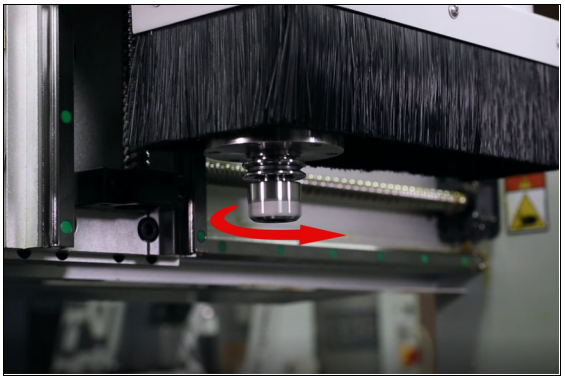


Figure 4-97: Spindle rotating counterclockwise.

4. Depending on the direction in which the spindle rotated in Step 3, do one of the following:
   - **Rotates Clockwise (Viewed from Above)** You've completed the spindle function verification. Go to "Align the ATC Rack" (below).
   - **Rotates Counterclockwise (Viewed from Above)** Power off the machine and, on the variable frequency drive (VFD), swap **wire U** and **wire V**. Then, power on the machine, and repeat Steps 2 through 3.

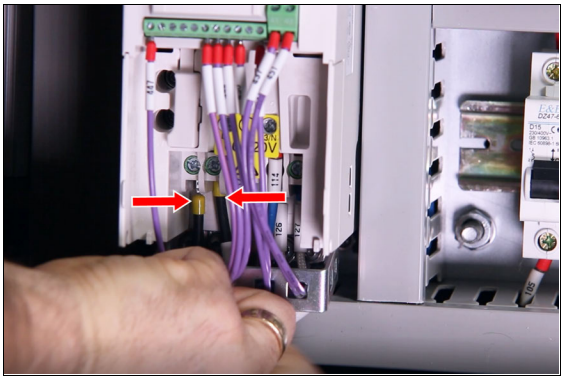


Figure 4-98: Wire U and wire V on the VFD.

4.11.17 Align the ATC Rack

Before using the 24R ATC for the first time, you must set the tool change positions for tool pockets A and J to align the ATC rack to the machine's reference position.

1. Install an ISO20 holder into the spindle.
2. Jog the machine in front of the left-most pocket (Pocket A) of the ATC rack.
3. Jog the spindle down to visually align the ATC fork with the tools holder's groove.

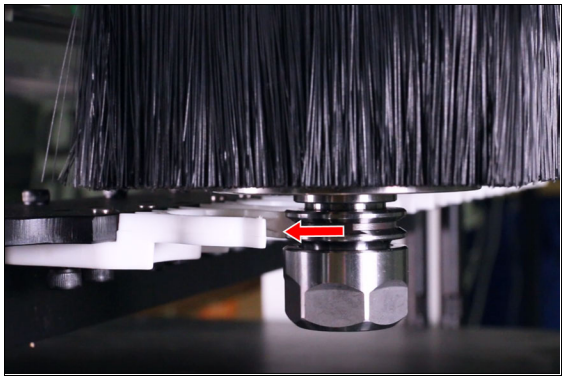


Figure 4-99: Aligning the ATC fork with the tool holder's groove.

4. Jog the machine in the Y+ direction to move the tool holder into the ATC rack while watching the tool fork. You want to see both forks start to bend out at the same time when the tool starts engaging the fork. Make any adjustments needed in the X direction.

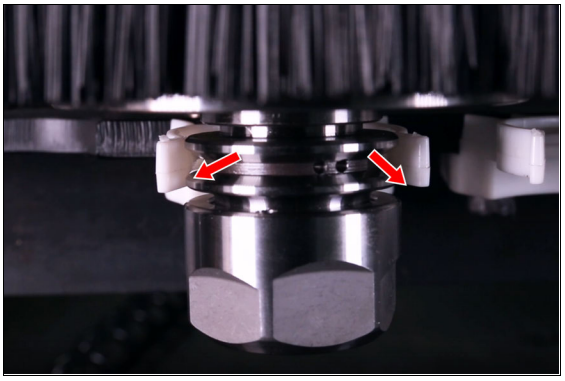


Figure 4-100: Tool forks bending out together.

5. Continue jogging the machine in the Y+ direction until the holder is seated in the ATC fork. You can determine this visually or by rotating the tool by hand. When the tool holder touches the back of the fork, you'll feel the drag increase.

Figure 4-101: Rotating the tool holder to feel when the drag increases.

6. From the PathPilot interface, select **Set TC POS** below pocket A to teach the location for Pocket A.

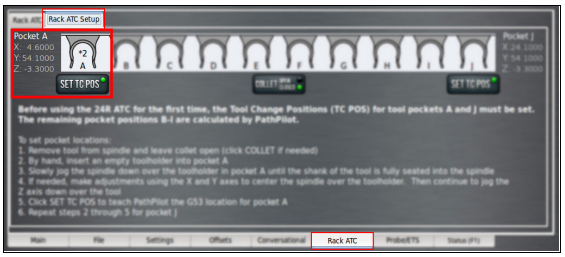


Figure 4-102: Set TOC POS button on Rack ATC Setup tab.

7. Jog the machine in the Y- direction to remove the tool from the ATC rack.

> **Note:** Keep the Z height at the same position to help reduce the setup time for Pocket J.

8. Jog the machine over to the right-most pocket (Pocket J), and repeat Steps 3-5.
9. From the PathPilot interface, **Set TC POS** below pocket J to teach the location for Pocket J.
10. Jog the machine in the Y- direction to remove the tool from the ATC rack.
11. You can make fine adjustments by directly editing the TC positions on the **Rack ATC Setup** tab. It's important to note that what's displayed are the G53 or machine coordinates. To have your machine's DRO match these values, you must:
    - Have a work coordinate active with all values set to 0, and
    - Have T0 active **or** a tool with a 0 in. offset.

4.11.18 Run the Spindle Break-In Program

To prolong bearing life and reduce spindle noise, it's important to run the spindle through a break-in procedure before operating the machine. Complete the following steps to run the spindle through a break-in cycle. You only must perform this procedure once for a new spindle.

> **Note:** The total cycle time for the spindle break-in procedure is **195 minutes**.

1. If you haven't yet done so, you must first install the spindle chiller before running this break-in program. For information, see the operator's manual.
2. Load a tool into the spindle. You can use an empty tool holder for this procedure.
3. From the PathPilot interface, on the **File** tab, open the **Examples** folder. Then, double click the program called **24R_spindle_breakin.ngc**.

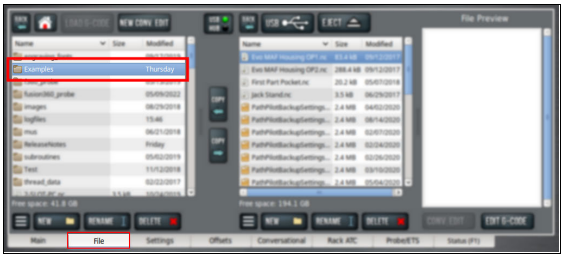


Figure 4-103: Examples folder on the File tab.

The program loads on the **Main** tab.

4. Select **Cycle Start**.
   The spindle runs through the three-hour break-in procedure, where it rotates in increments of 10,000, 20,000, and 24,000 rpm. After the program finishes, the break-in procedure is complete.

4.12 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).

4.12.1 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**.

4.12.2 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**.

4.12.3 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.

4.12.4 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**.

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

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

5.1.1 Machine Table

The machine table is 26.7" × 65" (680 mm × 1651 mm). It's a hybrid design that allows you to use:

- Vacuum fixturing (primary)
- Spoilboard fixturing
- Interchangeable pallets

There are three vacuum zones, each with a pair of dowel pins (which are 6 mm in diameter), and an M8 bolt pattern. Use the dowel pins to align pallets and fixtures to the surface of the machine table; use the M8 holes to fasten pallets, fixtures, or spoilboards to the machine table.

> ***NOTICE!*** Don't use the last 6 in. of phenolic table at the Y+ end of the machine as a working or load-bearing surface. If you do, it could cause damage to the phenolic table.

5.1.2 Spindle

The machine spindle uses an ER20 collet electrospindle.

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

About the Spindle

The machine spindle gives power to the cutting tool, which allows it to remove material from the workpiece. The spindle is driven by the spindle motor.
Operate the spindle either manually or by G-code commands (entered in the MDI Line DRO field or programmed into a G-code program).
The machine's spindle rotates clockwise (forward) at a specified spindle speed.

5.1.3 Axes

The machine has three linear axes of motion used for machining:

- The X-axis, which is (horizontally) along the width of the gantry.
- The Y-axis, which is (horizontally) along the length of the machine table.
- The Z-axis, which is (vertically) along the Z-axis linear rail plate.

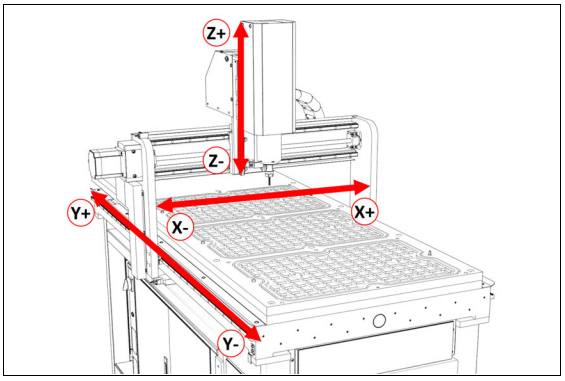


Figure 5-1: Axes directions on the machine.

Each axis has a different limit of travel, which is the distance it moves from its reference position (G53) before reaching a soft limit:

- **X-Axis** 24.75" (628 mm)
- **Y-Axis** 55.75" (1416 mm)
- **Z-Axis** 6.7" (170 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 left end 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 keyboard table (on the Controller Arm).
  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

5.3 CONNECTORS REFERENCE

- **A-Axis Motor Connector** On the front right end of the electrical cabinet.

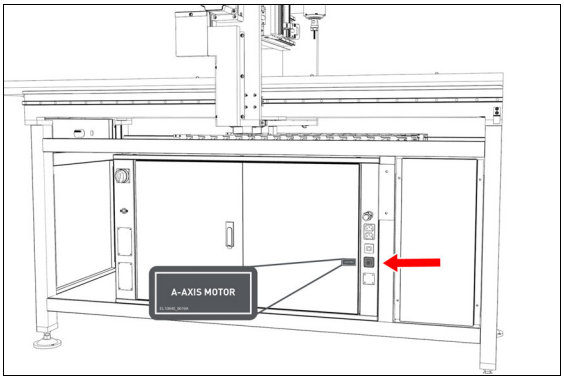


Figure 5-2: A-axis motor connector on the machine.

The A-axis motor connector is used to connect to a rotary 4th axis (used for indexing or continuous 4th axis machining).

- **Accessory Input (2x)**
  - **Accessory Input 1** On the operator side of the rear Z-axis cover.
  - **Accessory Input 2** Below the Main Disconnect switch on the electrical cabinet.

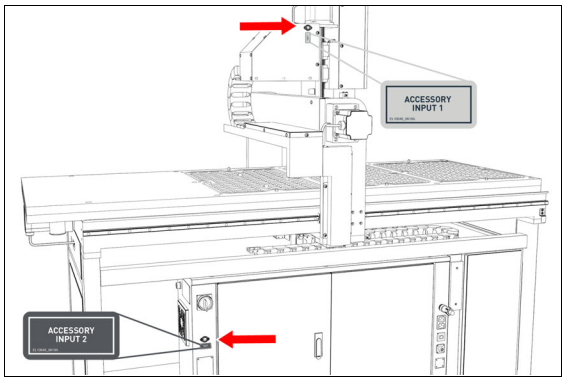


Figure 5-3: Accessory input ports on the machine.

The two accessory inputs are used to connect accessories (like probes, tool setters, and tool touch plates) to the machine.

- **Accessory Power Port (2x)** On the front right end of the electrical cabinet.

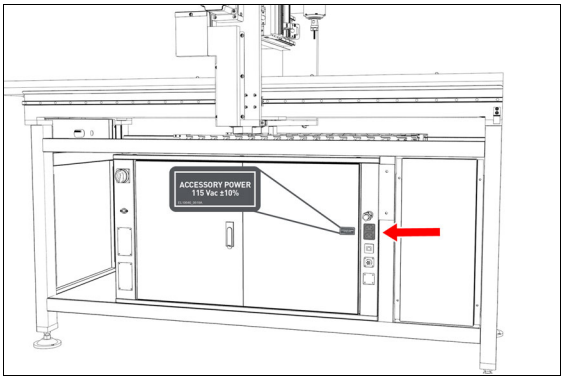


Figure 5-4: Accessory power ports on the machine.

The two IEC-320 accessory power ports are used to supply power to peripheral accessories (like the PathPilot controller and monitor). These outlets output 115 Vac ±10%.

- **Chiller Alarm Input** On the side of the left end of the electrical cabinet.

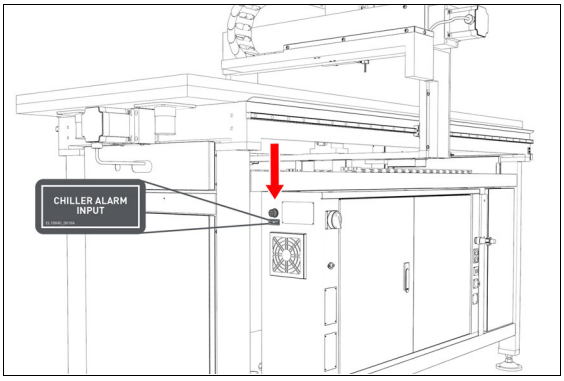


Figure 5-5: Chiller alarm input on the machine.

The chiller alarm input connects the alarm status feedback from the spindle chiller to the machine control system. This feedback allows the machine control system to stop the spindle from running while the chiller isn't working.

- **Compressed Air Line** At the back end of the machine underneath the phenolic table.

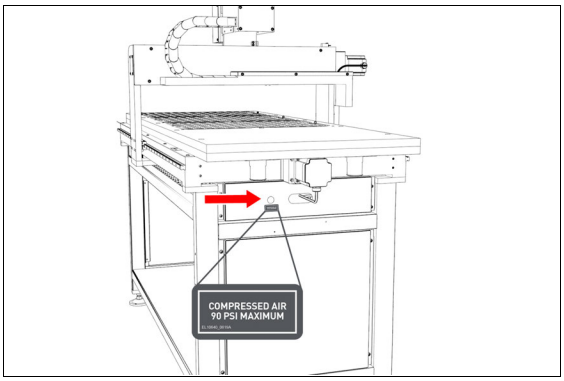


Figure 5-6: Compressed air line on the machine.

The compressed air line is used to supply accessories and components with compressed air.

- **Controller Communications Port** On the front right end of the electrical cabinet.

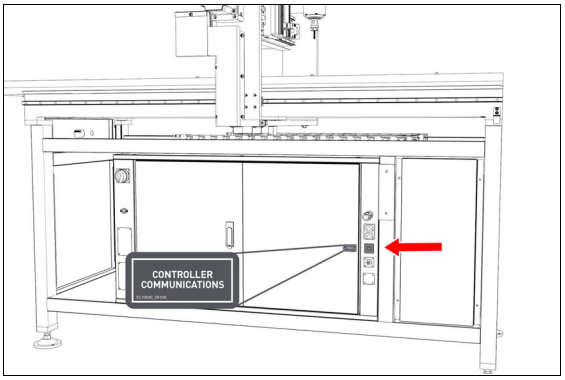


Figure 5-7: Controller communications port on the machine.

The controller communications port is used to connect the PathPilot controller to the machine. The controller communications port (and the cable that connects to it) sends all communication between the PathPilot interface and the machine.

- **Emergency Stop Input** On the front right end of the electrical cabinet.

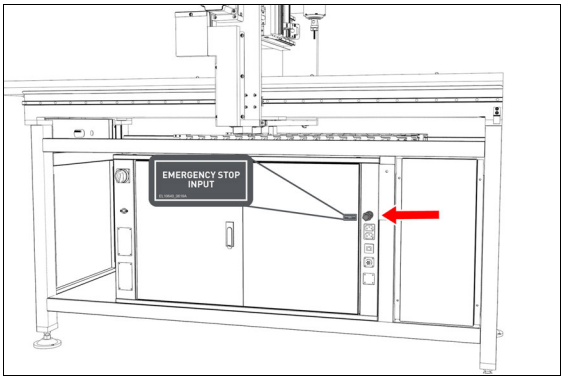


Figure 5-8: Emergency stop input on the machine.

PATHPILOT INTERFACE OVERVIEW

IN THIS SECTION, YOU'LL LEARN:

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

CONTENTS

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.

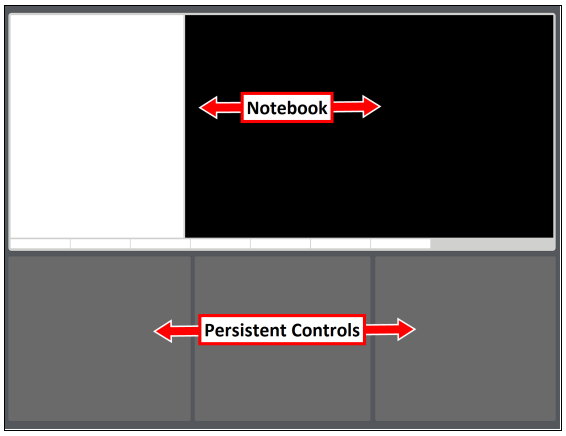


Figure 6-1: Sections in the PathPilot interface.

6.2 NOTEBOOK SECTION

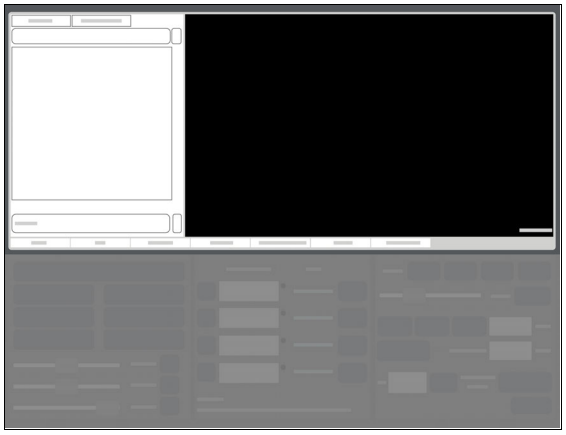


Figure 6-2: Notebook section.

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

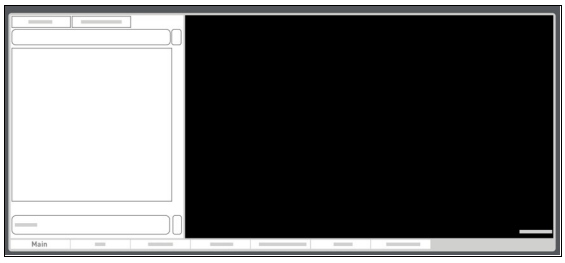


Figure 6-3: Main tab.

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 91); "Close the Current Program" (page 91).
- Send G-code commands directly to the machine using the Manual Data Input (MDI) Line DRO field.
  For information, see "Manually Enter Commands" (page 130).
- 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 92); "Expand the G-Code Tab" (page 92); "Change the View of the Tool Path Display" (page 94).

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 90).
- Edit G-code files.
  For information, see "Edit G-Code" (page 91).
- Load .nc files into PathPilot to run a program.
  For information, see "Load G-Code" (page 142).

- Move files within the system.
  For information, see "Preview G-Code Files" (page 90); "Manage System Files" (page 135).

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 108).
- Change the screen's layout orientation (landscape or portrait).
  For information, see "Change the Screen Orientation" (page 108).
- Configure PathPilot for the accessories you're using.
  For information, see "Enable the On-Screen Keyboard" (page 110); "Enable the USB M-Code I/O Interface Kit" (page 111); "Use a USB Camera" (page 112).
- Turn on feeds and speeds suggestions when using conversational programming.
  For information, see "Enable Feeds and Speeds Suggestions in Conversational Routines" (page 132).
- Disable the limit switches for troubleshooting.
  For information, see "Disable Limit Switches" (page 109).
- Specify the way in which you want to use a G30 move.
  For information, see "Limit G30 Moves" (page 110).
- Identify the available G-code modes that you can use.
  For information, see "View Available G-Code Modes" (page 123).

6.2.4 Offsets Tab

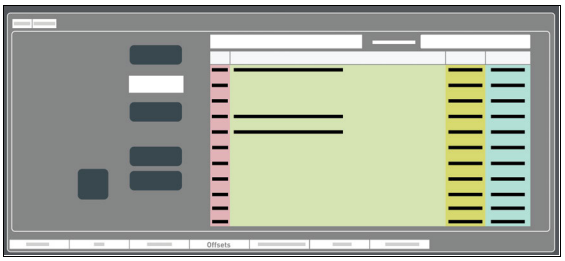


Figure 6-6: Offsets tab.

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 135); "Restore Backup Files" (page 136).
- Import and export .csv files of your tool table.
  For information, see "Import and Export the Tool Table" (page 137).
- Work with a table of tool descriptions and tool offsets.
  For information, see "Set Tool Length Offsets" (page 143).
- Use an Electronic Tool Setter (ETS) to measure tools.
  For information, see "Use an Electronic Tool Setter (ETS) to Measure Tools" (page 117).
- Preset a G30 position.
  For information, see "Use a G30 Position" (page 129).
- Read the currently programmed work offsets.
  For information, see "View Work Offsets" (page 122).

6.2.5 Conversational Tab

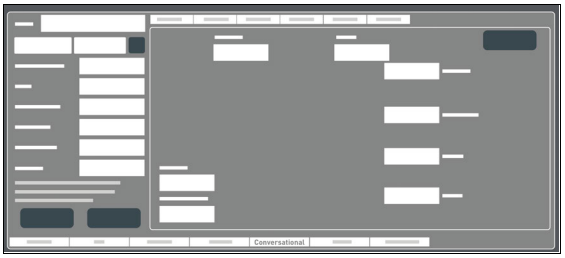


Figure 6-7: Conversational tab.

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 95).

6.2.6 Probe Tab

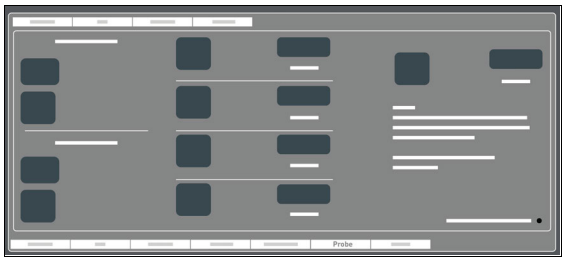


Figure 6-8: Probe tab.

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 115).
- Configure and control an Electronic Tool Setter (ETS) to help perform certain functions.
  For information, see "Use an Electronic Tool Setter (ETS) to Measure Tools" (page 143).

6.2.7 Status Tab

Figure 6-9: Status tab.

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

- View diagnostic machine information.
- Read error messages.
- Configure your internet connection.
  For information, see "Enable an Internet Connection" (page 106).
- 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

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 123).
- Start, stop, or pause a G-code program.
  For information, see "Start a Program" (page 125); "Stop Machine Motion" (page 125); "Use the Feed Hold Function" (page 126).

- Use overrides to change the feed rate, spindle speed, and maximum velocity.
  For information, see "Use the Feed Rate Override Function" (page 126); "Use the Maxvel Override Function" (page 127); "Use the Spindle Override Function" (page 128).
- Manually control a G-code program.
  For information, see "Use M01 Break Mode" (page 127); "Use Single Block Mode" (page 128).

6.3.2 Position Status Area

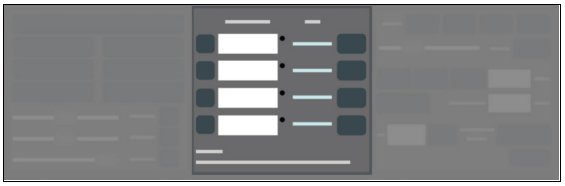


Figure 6-12: Position Status area.

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 140).
- Create work offsets.
  For information, see "Set Work Offsets" (page 147).
- Understand how you're jogging the machine.
  For information, see "View the Active Axis to Jog" (page 123); "View the Current Machine Position" (page 124); "View the Distance to Go" (page 126).
- Quickly determine which G-code modes are active.
  For information, see "View the Active G-Code Modes" (page 126).

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 140).
- Change the spindle speed or feed rate.
  For information, see "Change the Spindle Speed" (page 129); "Change the Feed Rate" (page 128).
- View or edit information about the current tool.
  For information, see "Change the Tool Number" (page 129); "Use a G30 Position" (page 129) "View the Tool Length" (page 130).

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+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**.

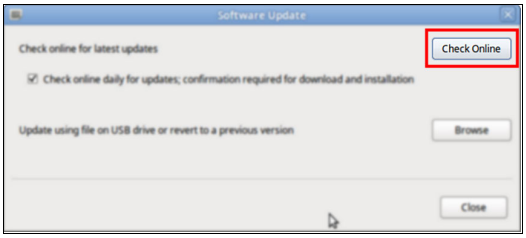


Figure 6-15: Software Update dialog box.

4. Select **Install**.

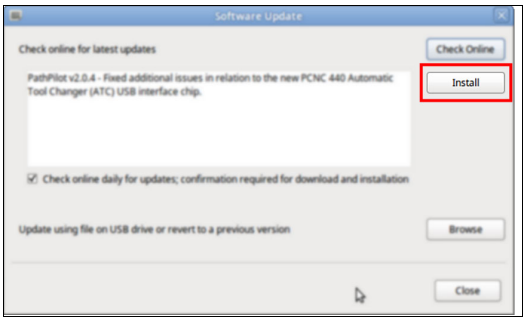


Figure 6-16: Install button on the Software Update dialog box.

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**.

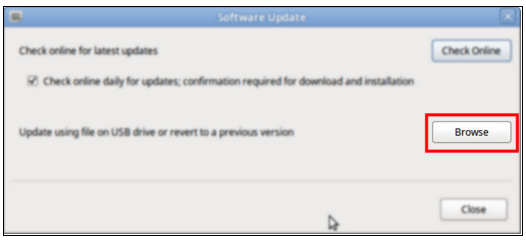


Figure 6-18: Software Update dialog box.

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**.

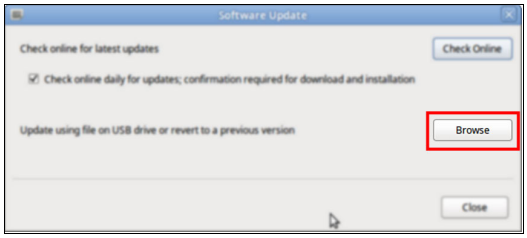


Figure 6-21: Software Update dialog box.

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

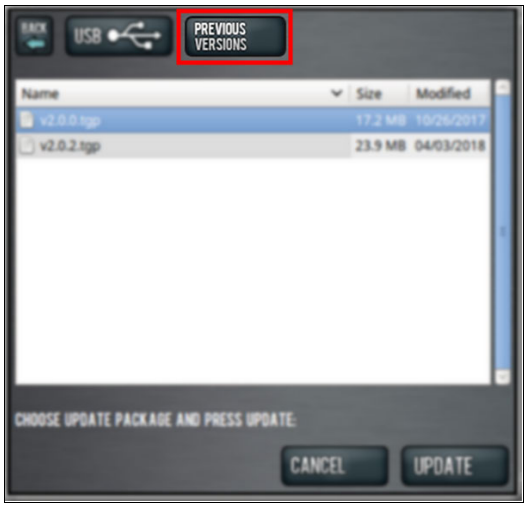


Figure 6-22: Browse dialog box.

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.

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

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

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**.

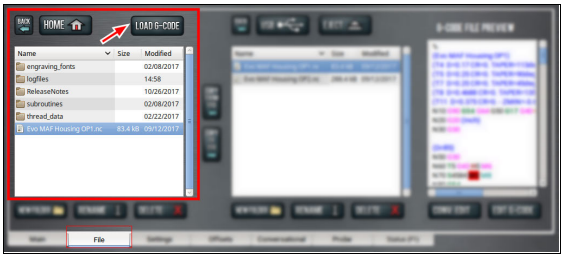


Figure 7-1: Controller Files window on the File tab.

> **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 135).

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**.

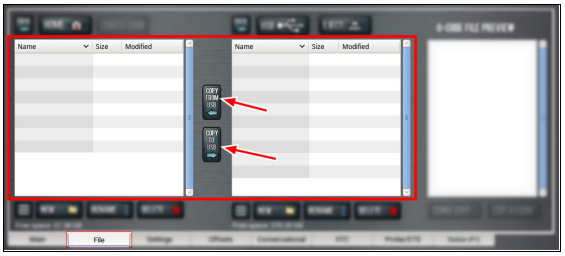


Figure 7-2: File tab.

> **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

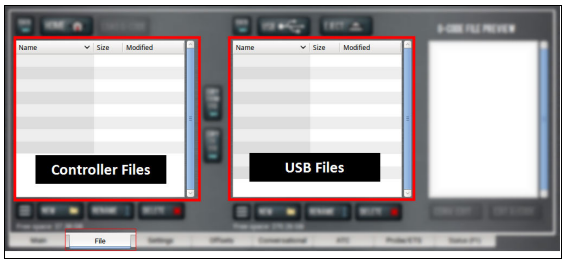


Figure 7-3: File tab.

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.

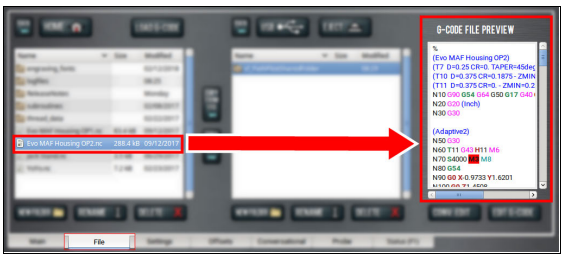


Figure 7-4: File tab.

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.

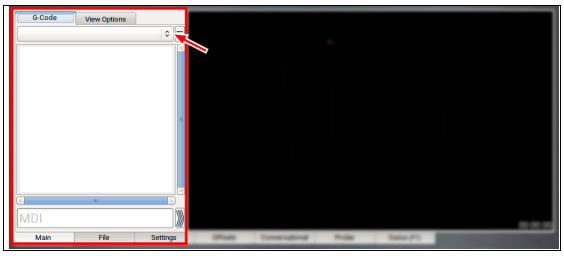


Figure 7-5: Recent Files menu on the Main tab.

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**.

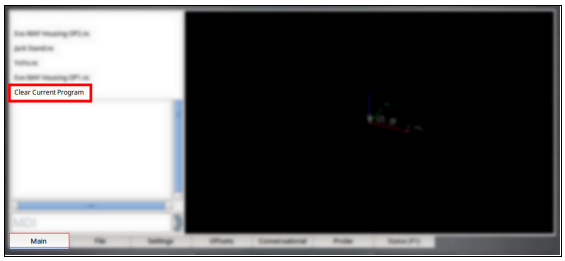


Figure 7-6: Recent Files menu on the Main tab.

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

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.

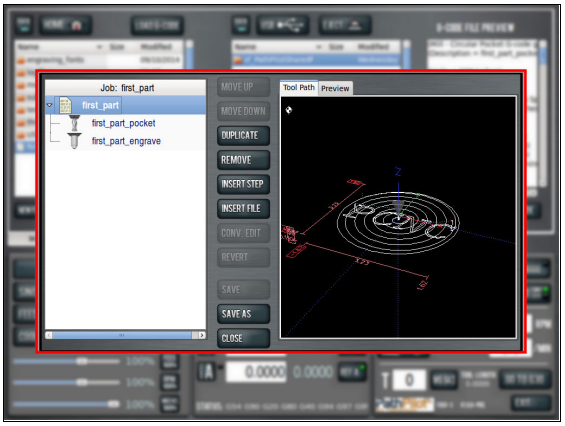


Figure 7-8: Job assignment editor.

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

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

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**.

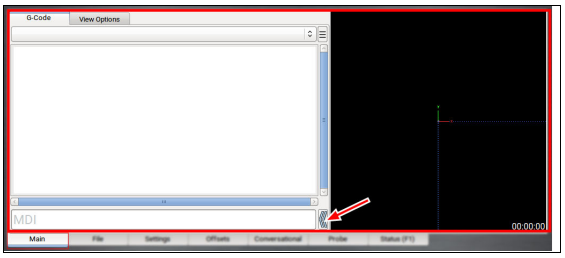


Figure 7-9: Window Expander on the Main tab.

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.

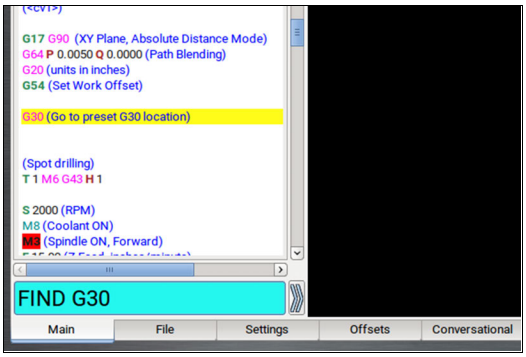


Figure 7-10: Search for a text command.

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

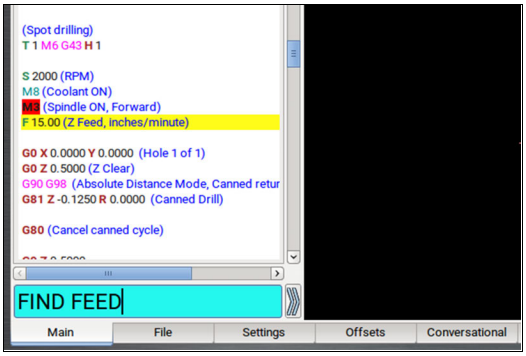


Figure 7-11: Search for a feed command.

   - `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.

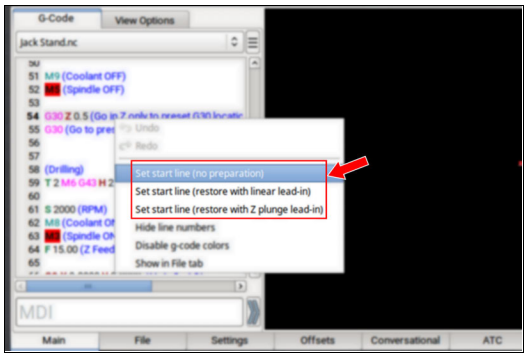


Figure 7-12: Accessing the Options menu by right-clicking.

   - 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.

> **E X A M P L E**

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.

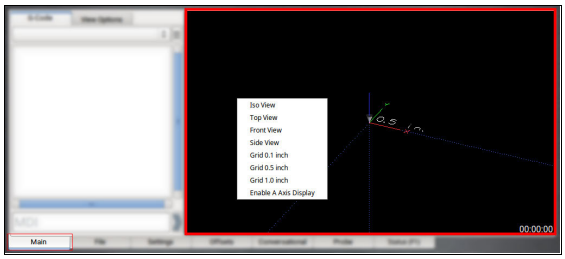


Figure 7-13: Tool Path display on the Main tab.

   - Select the **View Options** tab.

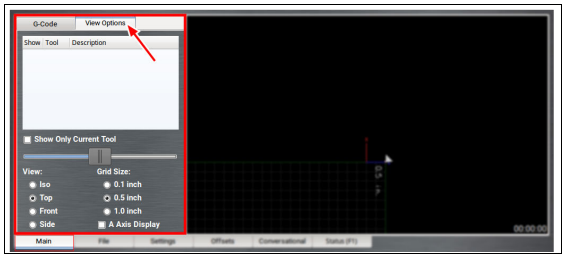


Figure 7-14: View Options tab on the Main tab.

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

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.

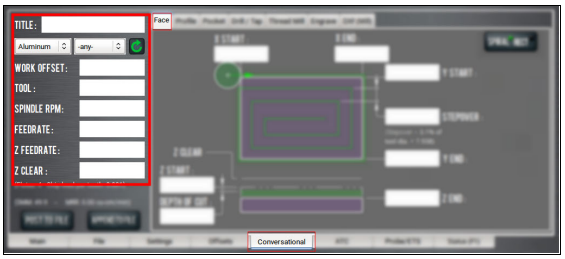


Figure 7-15: Conversational DROs on the Face tab.

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).

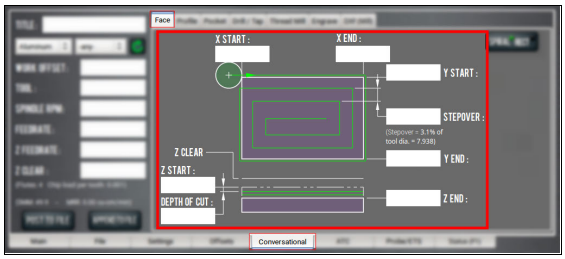


Figure 7-16: Program-specific DROs on the Face tab.

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.

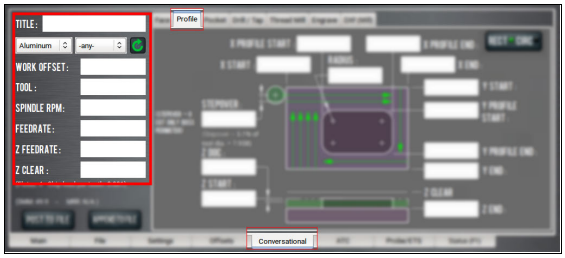


Figure 7-17: Conversational DROs on the Profile tab.

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).

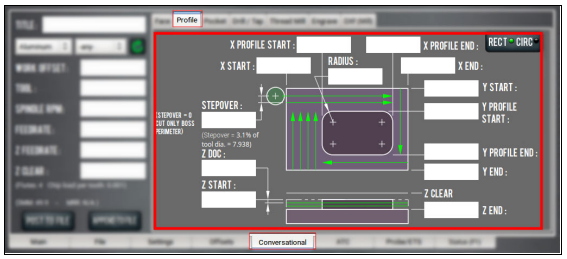


Figure 7-18: Program-specific DROs on the Profile tab.

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 96).

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:

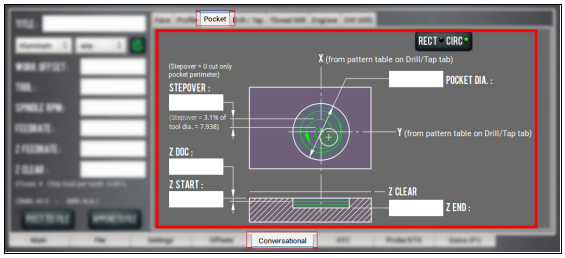
1. From the **Conversational** tab, select the **Pocket** tab.
2. From the **Conversational DROs** group, set the parameters for the pocket operation.

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).

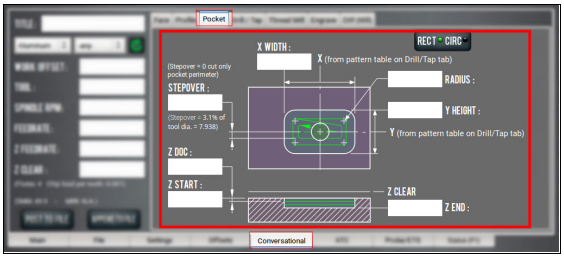


To create a rectangular pocket on a part:

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 tab.

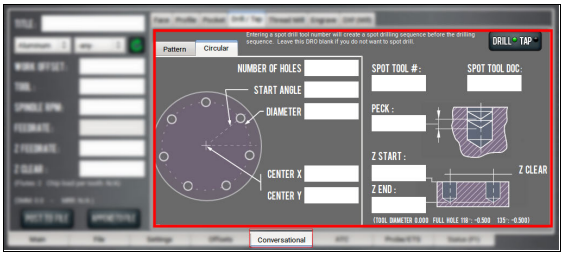


Figure 7-19: Drill/Tap tab on the Conversational tab.

2. From the 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.

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 tab.

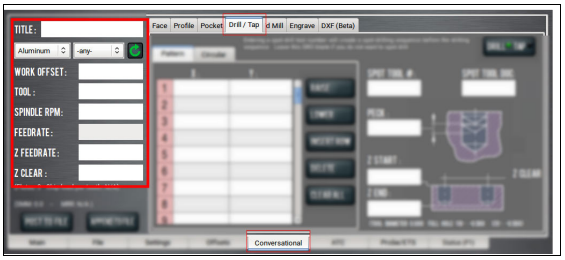


Figure 7-20: Drill/Tap tab on the Conversational tab.

2. From the 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.

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

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 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.

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" (below).

4. Set the parameters for the hole in the Z range:
   a. In the **Z Start** DRO field, type the location for the first Z pass.
   b. In the **Z End** DRO field, type the location for the last Z pass.

Drilling and Tapping Reference

PathPilot uses the following terms when drilling 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.

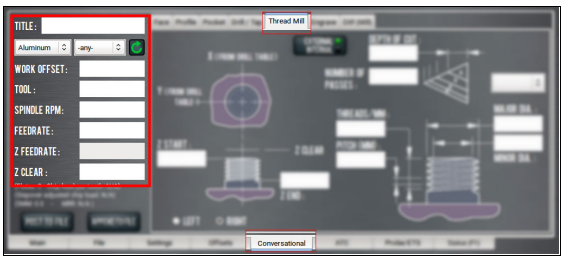


Figure 7-21: Conversational DROs on the Thread Mill tab.

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.

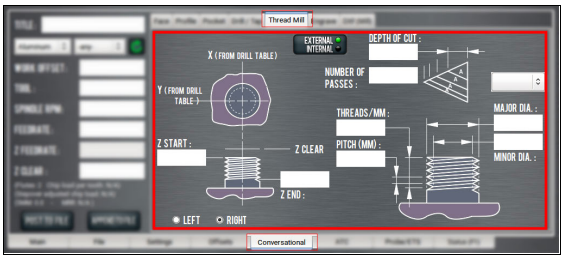


Figure 7-22: Program-specific DROs on the Thread Mill tab.

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" (on the next page).
To create an engraving sequence on a part:

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

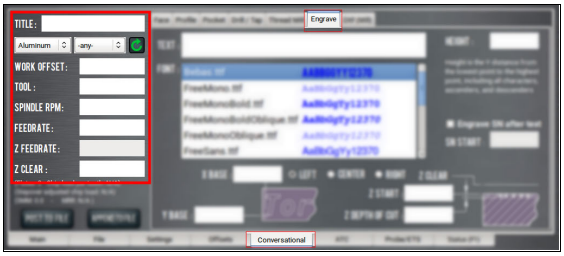


Figure 7-23: Conversational DROs on the Engrave tab.

3. Work through the program-specific DRO fields:
   a. In the **Text** DRO field, type the desired text to engrave.
   The text appears in the **Preview** window.
   b. From the **Font** list, select the desired font for the engraved text.

> **Note:** To search the **Font** list, select a font and begin typing the font's name. PathPilot scrolls to the result.

   The **Preview** window updates to display the font selected.

> **Note:** You can add True Type font files to the PathPilot controller. For information, see "Transfer Files to and From the Controller" (page 90).

   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.

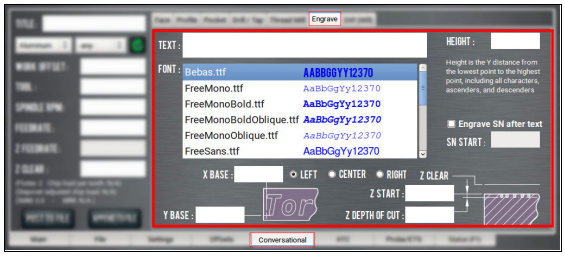


Figure 7-24: Program DROs on the Engrave tab.

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.

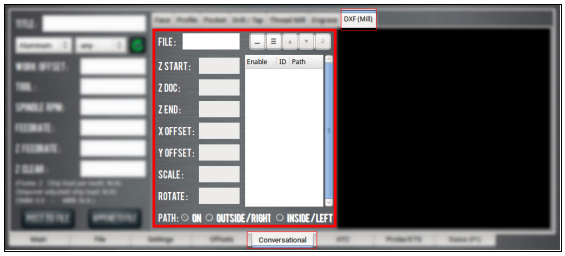


Figure 7-25: DXF tab on the Conversational tab.

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 90).

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.

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.

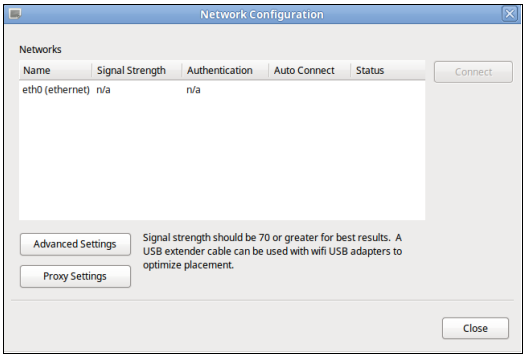


Figure 7-27: Network Configuration dialog box.

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.

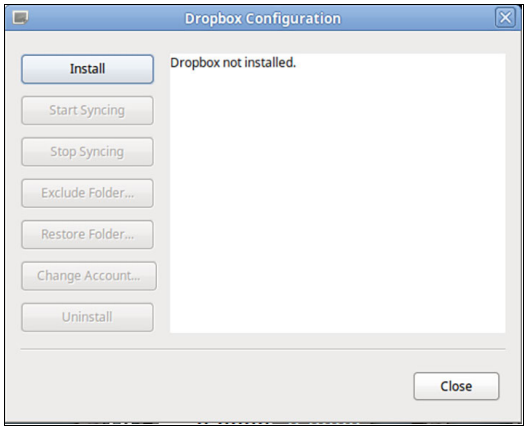


Figure 7-28: Dropbox Configuration application.

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...**.

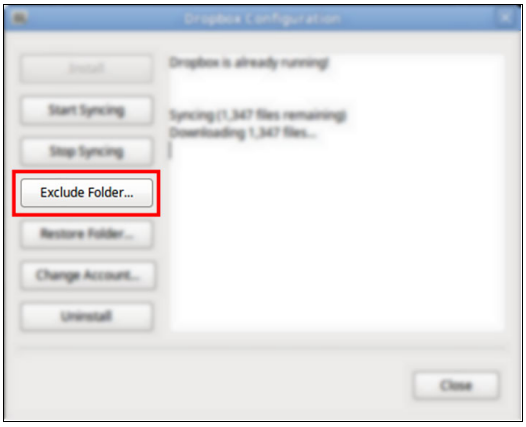


Figure 7-30: Exclude Folder button.

   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.

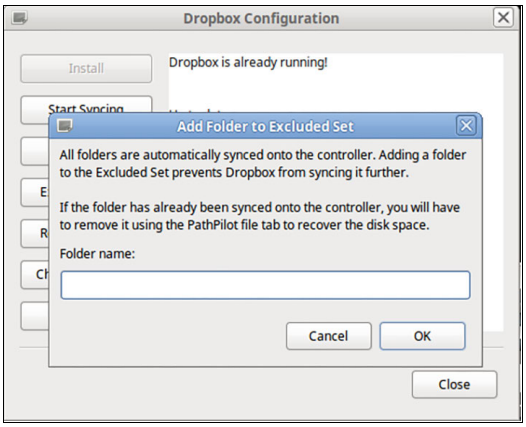


Figure 7-31: Add Folder to Excluded Set dialog box.

> **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.

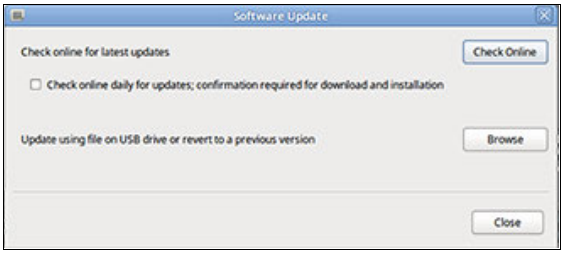


Figure 7-32: Software Update dialog box.

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.

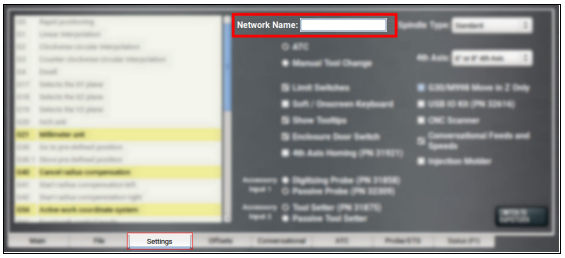


Figure 7-33: Network Name field on the Settings tab.

> **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 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" (below).

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.

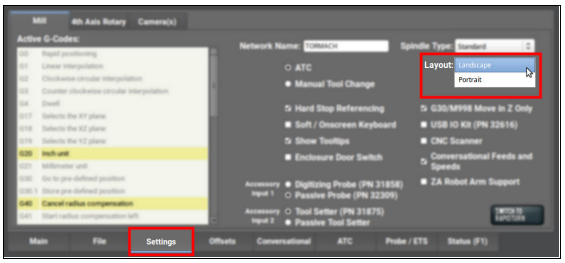


Figure 7-34: Layout drop-down menu on the Settings tab.

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.

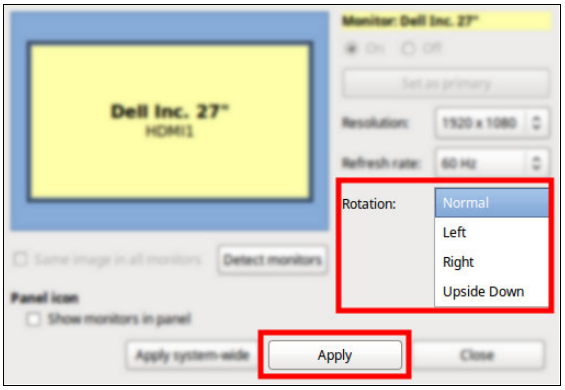


Figure 7-35: Monitor configuration dialog box.

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.

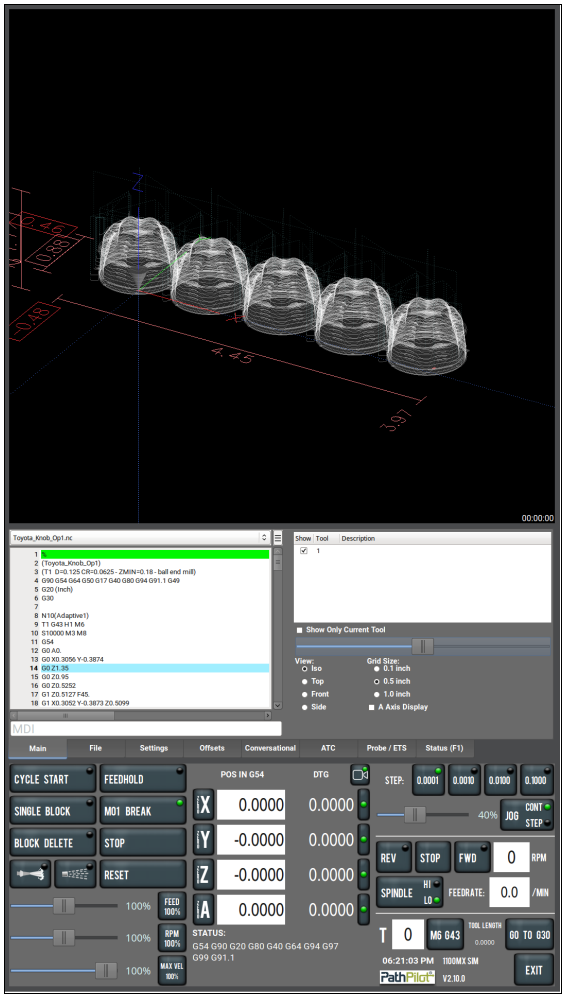


Figure 7-36: Tool Path window in portrait screen layout.

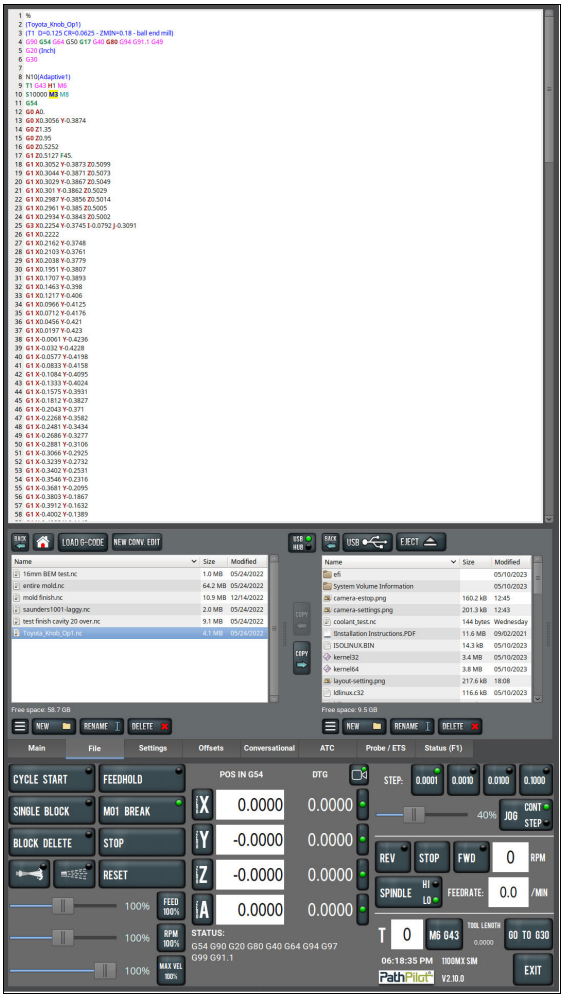


Figure 7-37: File tab G-code preview in portrait screen layout.

- 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.

7.2.4 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" (on the next page).

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

To disable limit switches:

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

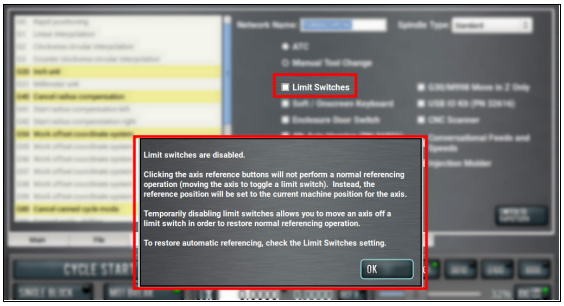


Figure 7-38: Limit Switches checkbox on the Status tab.

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.

About Limit Switches

In the PathPilot interface, on the Settings tab, the Limit Switches checkbox is selected by default.
If the checkbox is cleared, the machine completes a unique referencing procedure after selecting Ref X, Ref Y, Ref Z, and Ref A: rather than moving each axis to the end of its travel, the reference position is set as the machine's current position. This is useful for troubleshooting: if the limit switches are disabled, you're able to move the axis off of its limit switch.

7.2.5 Limit G30 Moves

You can limit G30 moves so that only the Z-axis moves. For information, see "About G30" (page 130).
To limit G30 moves:

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

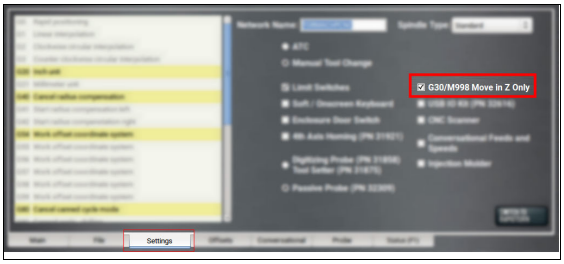


Figure 7-39: Settings tab.

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 129).
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.

7.2.6 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" (on the next page).
To enable and use the soft (on-screen) keyboard:

1. From the **Settings** tab, select **Soft / On-Screen Keyboard**.

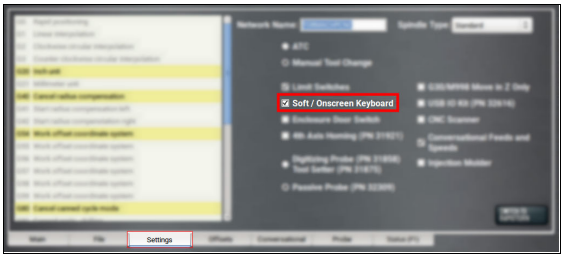
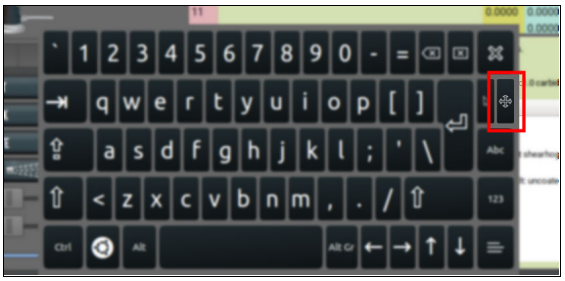
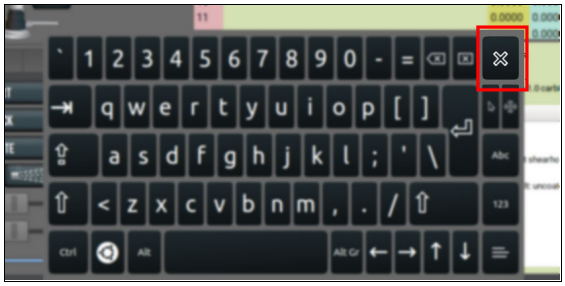


Figure 7-40: Settings tab.

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 7-41: Soft (on-screen) keyboard.

7.2.7 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)**.

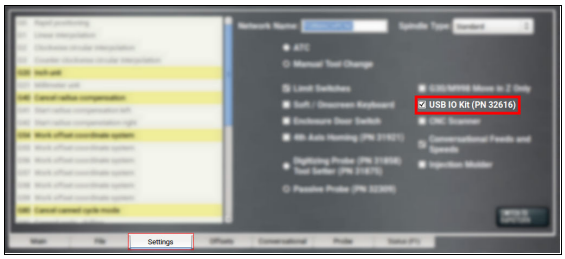


Figure 7-42: Settings tab.

7.2.8 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**.

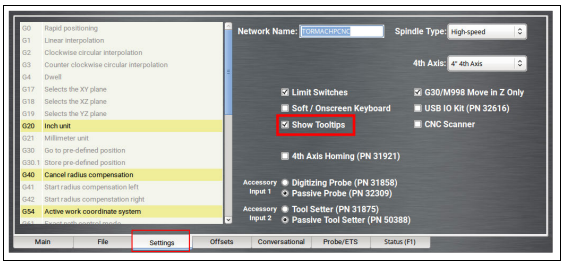


Figure 7-43: Show Tooltips checkbox.

> **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.

7.2.9 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)
- Tool Setter for 24R (PN 50388)

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**.

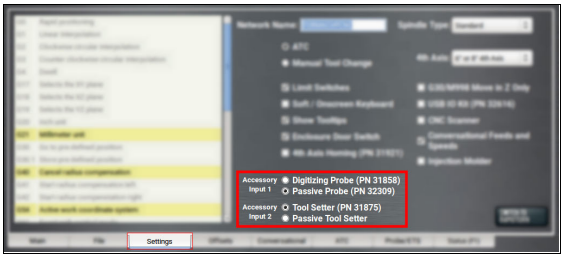


Figure 7-44: Settings tab.

7.2.10 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 131).

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

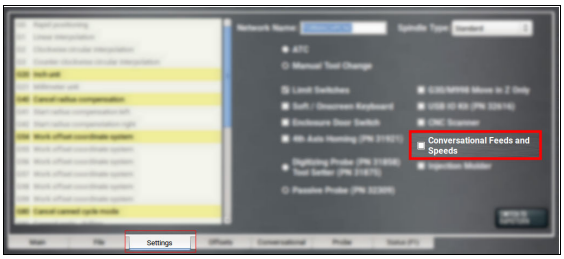


Figure 7-45: Settings tab.

7.2.11 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 7-46: 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 7-47: Manual recording controls.

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

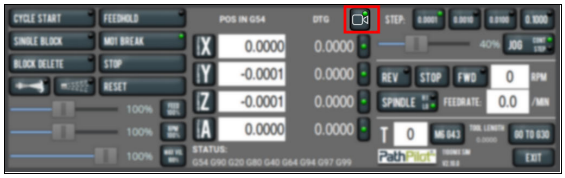


Figure 7-48: Video Camera Recording button.

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 7-49: 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.

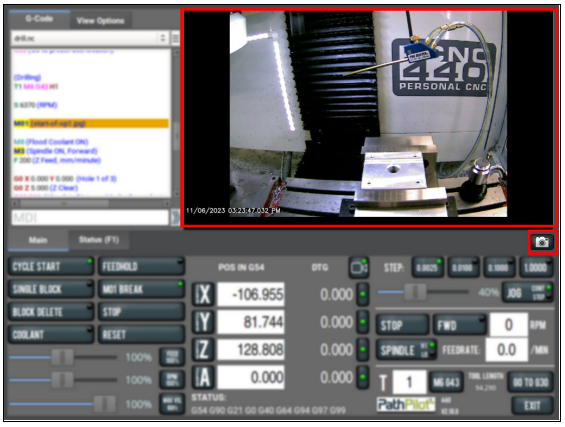


Figure 7-50: Example of taking a photo.

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 171).

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

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 111).

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-**.

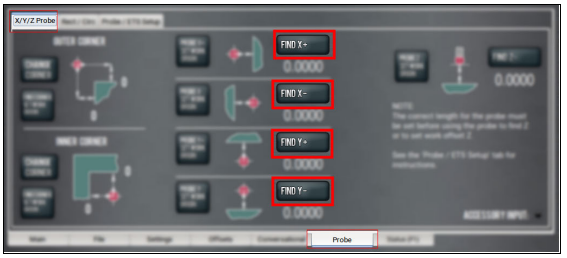


Figure 7-51: Probe tab.

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**.

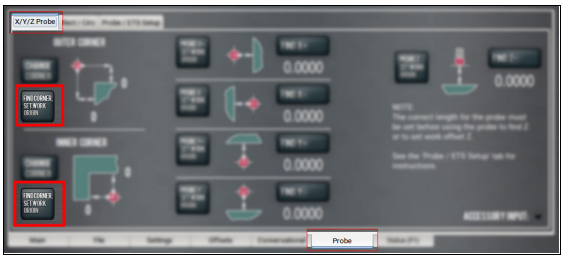


Figure 7-52: Probe tab.

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**.

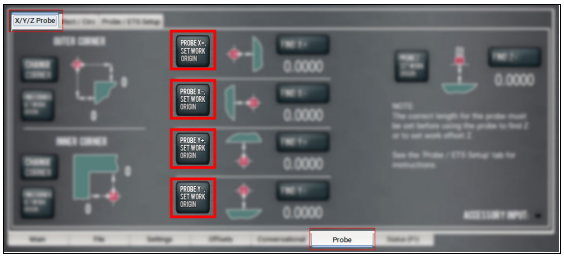


Figure 7-53: Probe tab.

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.

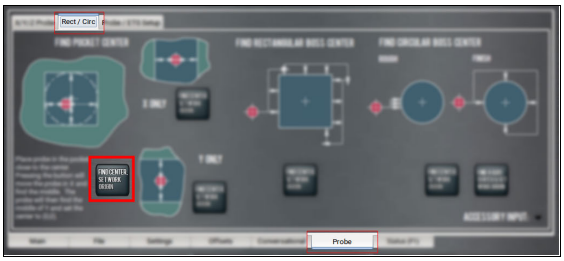


Figure 7-54: Probe tab.

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.

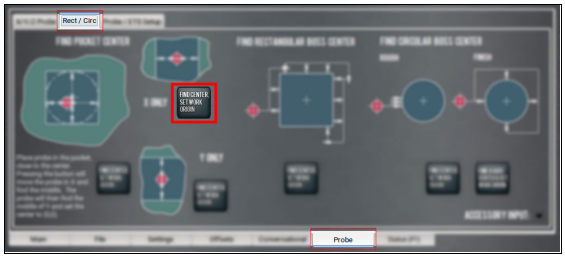


Figure 7-55: Probe tab.

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

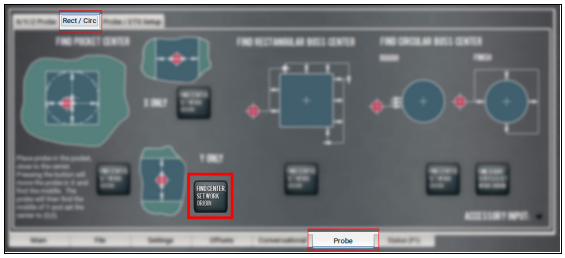


Figure 7-56: Probe tab.

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.

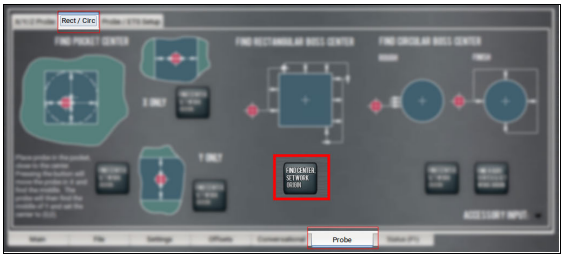


Figure 7-57: Probe tab.

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.

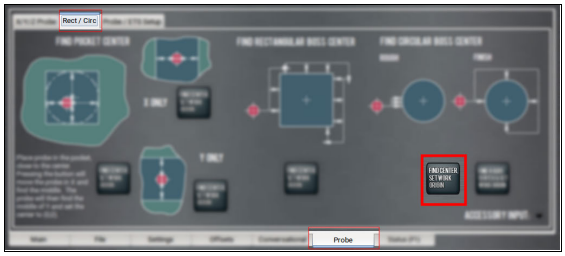


Figure 7-58: Probe tab.

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**.

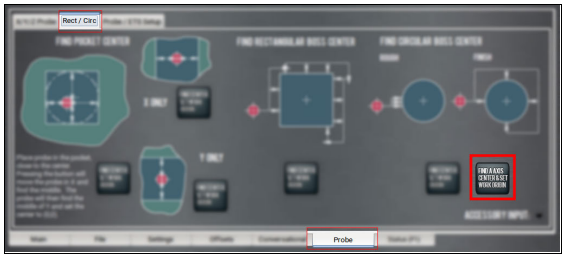


Figure 7-59: Probe tab.

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 147).

> **Note:** You can import a .csv file with tool length offset data. For information, see "Import and Export the Tool Table" (page 137).

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

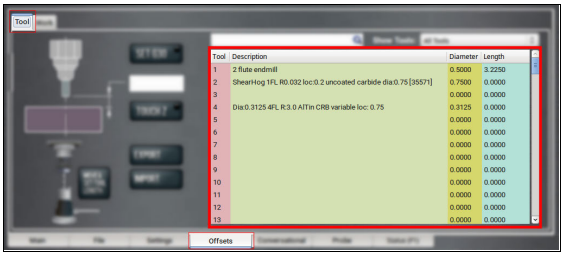


Figure 7-60: Tool Table window on the Offsets tab.

5. Depending on your workflow, you can measure your tools using any of the following methods:
   - **Use an Electronic Tool Setter** For information, see "Use an Electronic Tool Setter (ETS) to Measure Tools" (below).
   - **Touch Off of a Known Reference Height** For information, see "Touch Off the Tool Length Offsets" (page 145).

Use an Electronic Tool Setter (ETS) to Measure Tools

An Tool Setter for 24R (PN 50388) 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. From the PathPilot interface, on the **Offsets** tab, in the **Tool Table** window, in the **Description** column, type a description for the tool.
3. In the **Diameter** column, type the diameter of the tool. Then select the **Enter** key.
4. From the PathPilot interface, type the tool number in the **Tool** DRO field. Then select the **Enter** key.

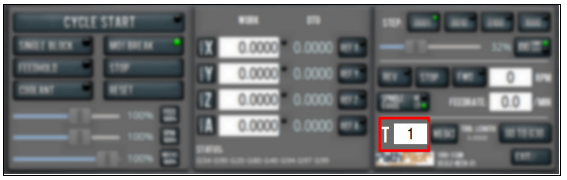


Figure 7-61: Tool DRO field.

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

Set up the Electronic Tool Setter (ETS)

There are three steps to set up the ETS. Complete the following steps in the order listed:

Set the ETS Height

Before you begin to use the ETS, you must first use the PathPilot interface to set its work offset.

To set the ETS height:

1. Set a new Z zero position for the currently selected work offset.
   For information, see Set a Known Reference Height.
2. Put the ETS on the known reference height (from Step 1).
3. Jog the spindle until it's over the ETS.
4. From the PathPilot interface, on the **Probe** tab, select the **ETS Setup** tab. Then find the **ETS Work Offset Setup** group, and select **Move & Set ETS Height**.

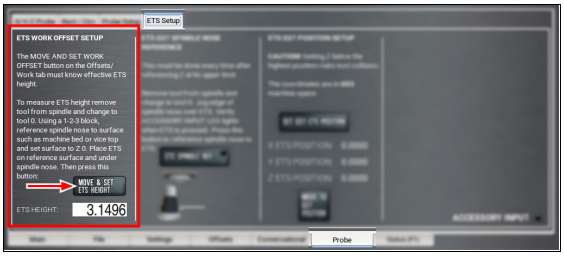


Figure 7-62: Move & Set ETS Height button on the Probe tab.

   The Z-axis moves down (-Z) until the spindle nose contacts and triggers the ETS.
5. In the **ETS Height** DRO field, verify that the length of the ETS updated.

Reference the Spindle Nose

Note: You must repeat this procedure after each time that you reference the Z-axis.

1. Identify a home location for your ETS. You can use anywhere within the machine's area of travel as the home location, so long as you can center the spindle above the ETS.

Tip! We recommend putting the ETS toward the Y+ end of travel (where it's outside of the 2 ft × 4 ft standard work envelope, and on the surface of the vacuum table). For information, see "ETS Placement Layout" (page 233).

2. Remove the collet nut and the tool from the spindle.
3. From the PathPilot interface, in the **Tool** DRO field, type `0`. Then select the **Enter** key.
4. Jog the spindle until it's over the ETS. Then, slowly jog the Z-axis down (-Z) toward the contact pad on the ETS.
5. From the PathPilot interface, on the **ETS Setup** tab, find the **ETS G37 Spindle Nose Reference** section, and select **ETS Spindle Ref**.

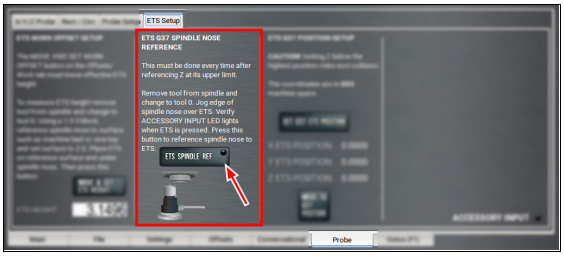


Figure 7-63: ETS Spindle Ref button on the Probe tab.

   The Z-axis moves down (-Z) until the spindle nose contacts and triggers the ETS.
   The spindle nose is now referenced to the ETS.

Set the G37 Position

1. Remove the collet nut and the tool from the spindle.
2. From the PathPilot interface, in the **Tool** DRO field, type `0`. Then select the **Enter** key.
3. Jog the spindle until it's over the ETS, and center the spindle over its contact pad.
4. Jog the Z-axis up (+Z) until it's at a safe clearance height for your longest tool.

NOTICE! If the Z-axis is set below the highest position, there's a risk of tool collision.

5. From the PathPilot interface, on the **ETS Setup** tab, find the **ETS G37 Position Setup** group, and select **Set G37 ETS Position**.

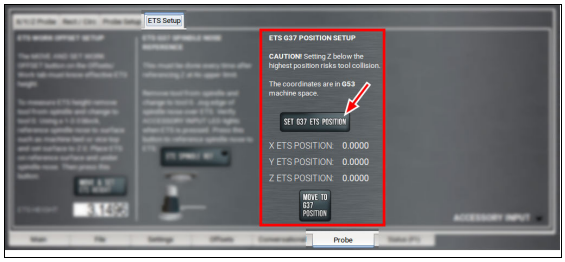


Figure 7-64: Set G37 ETS Position on the Probe tab.

The G37 position is now set.

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

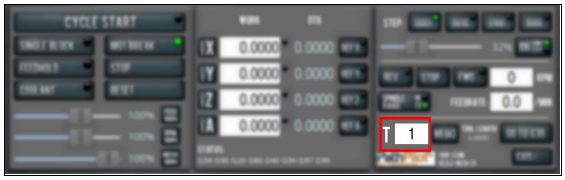
> **Note:** The values displayed in these DRO fields are in G53.

Measure Tools Using an Electronic Tool Setter (ETS)

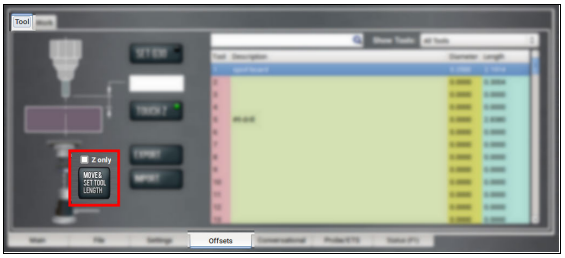
Depending on your workflow, do one of the following:

Manually Measure Tool Lengths (with PathPilot)

1. Plug in the ETS to the **Accessory 2** port.
2. Set up the ETS.
   For information, see "Set up the Electronic Tool Setter (ETS)" (page 143).
3. Put the ETS in its home position (that you determined in "Set up the Electronic Tool Setter (ETS)" (page 143)).
4. From the PathPilot interface, on the **Offsets** tab, in the **Tool Table** window, in the **Description** column, type a description for the tool.
5. In the **Diameter** column, type the diameter of the tool. Then select the **Enter** key.
6. Install a tool into the spindle.
7. From the PathPilot interface, type the tool number in the **Tool** DRO field. Then select the **Enter** key.



8. On the **Offsets** tab, find the **Move and Set Tool Length** button and the **Z only** checkbox. Verify that the checkbox is cleared, and then select **Move and Set Tool Length**.



> **Note:** You should only use the **Z only** checkbox to manually measure tools with a larger diameter. When it's selected, the machine doesn't go to the G37 position — instead, it just moves straight down (Z-) to measure the tool.

The machine moves to the G37 position and measures the tool with the ETS.

> **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.

Automatically Measure Tool Lengths (with G37)

We recommend using the G37 G-code command to measure tools. This method simplifies the tool measurement procedure — you're letting the machine do the work for you — but it also increases tool length accuracy and reduces tool change times in multi-tool programs.

Depending on your workflow, do one of the following:

- **Use G37 in the MDI Line DRO Field**
  1. Set up the ETS.
     For information, see"Set up the Electronic Tool Setter (ETS)" (page 143).
  2. Put the ETS in its home position (that you determined in "Set up the Electronic Tool Setter (ETS)" (page 143)).
  3. Put a tool into the spindle and tighten the collet nut.

4. From the PathPilot interface, in the **MDI Line** DRO field, type `G37`. Then select the **Enter** key.
   The spindle moves to the ETS position, measures the length of the tool, and applies that length to the currently selected tool in the tool offsets table.

- **Use G37 in a G-Code Program**
  1. Set up the ETS.
     For information, see"Set up the Electronic Tool Setter (ETS)" (page 143).
  2. From the PathPilot interface, load a G-code program with a G37 command.
  3. Select **Cycle Start**.
     When the program reaches the G37 command, the machine moves to the ETS and measures the length of the tool.

For information, see "Programming" (page 149).

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

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 147).
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 141).

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.

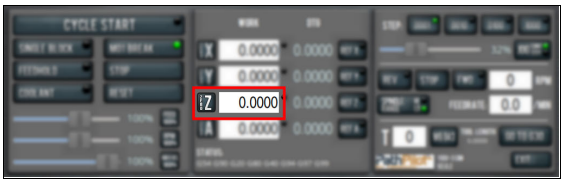


Figure 7-65: Z-axis work offset DRO field.

   The reference surface is now set as the Z zero position in the current coordinate system.
10. To set the tool length offset, go to Measure Tools Using a Known Reference Height.

Measure Tools Using a Known Reference Height

This procedure sets the tool length offset using a known reference height. If you have not yet done so, you must first set the Z zero position; go to Set a Known Reference Height.
To measure tools using a known reference height:

1. Verify that the reference surface is still on the machine table with the piece of paper.
2. From the PathPilot interface, on the **Offsets** tab, find an unused tool number in the **Tool Table** window. Then, type a description for the tool you're measuring.
3. Put the tool holder into the spindle.

4. From the PathPilot interface, in the **Tool** DRO field, type the number of the tool. Then select the **Enter** key.

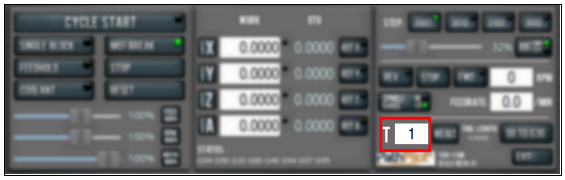


Figure 7-66: Tool DRO field.

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.

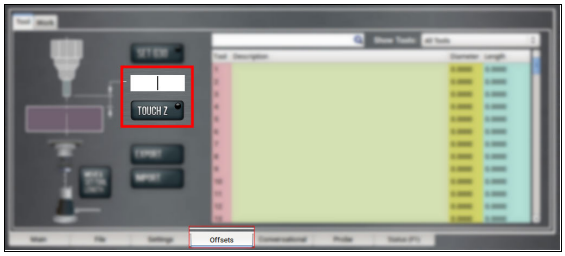


Figure 7-67: Touch Z DRO field and button.

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.

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 tip of the tool to the spindle nose. Because the ER20 collet spindle doesn't provide a repeatable tool length, the tool length must be measured every time that you remove a tool from the spindle. To speed up tool changes, we recommend using an Electronic Tool Setter (PN 31875) when measuring tool lengths.

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.

7.3.3 Set Work Offsets

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

➢ Select **Zero [Axis]**.

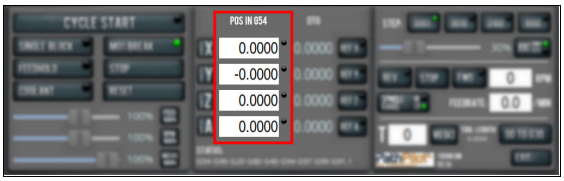


Figure 7-68: Work Offset DRO fields.

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 7-69: 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 148).

Set the Z-Axis Work Offset with an Electronic Tool Setter (ETS)

1. Set up the ETS.
   For information, see "Set up the Electronic Tool Setter (ETS)" (page 143).
2. Install a tool into the spindle.
   For information, see Install a Tool in an ER Collet Tool HolderSpindle.
3. Use the ETS to measure the length of the tool in the spindle.
   For information, see "Set Tool Length Offsets" (page 143).
4. Put the ETS on the surface that you want to set as Z zero.
5. Jog the spindle until the tool is centered over the ETS.
6. From the PathPilot interface, on the **Offsets** tab, on the **Work** tab, select **Move and Set Work Offset**.

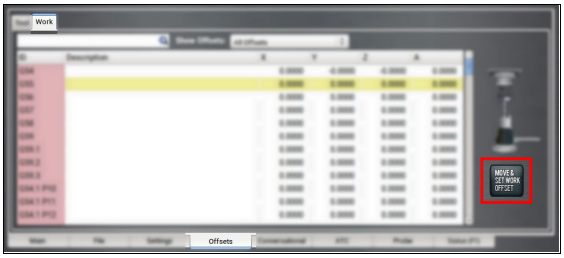


Figure 7-70: Work tab on the Offsets tab.

The machine moves down (-Z) until the tool contacts the ETS. The Z-axis offset updates for the current work offset.

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.

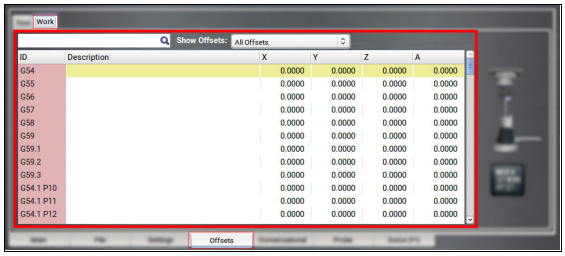


Figure 7-71: Work Offsets Table window.

The active work offset is highlighted.

To change the current work offset, go to "Set Work Offsets" (page 147).

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.

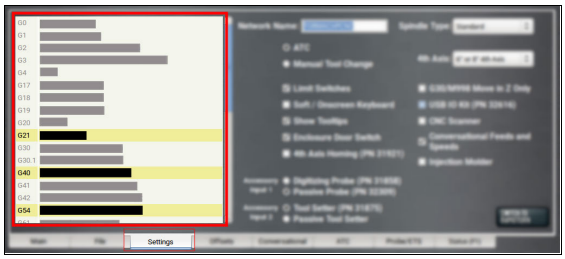


Figure 7-72: G-code Description window on the Settings tab.

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

- Select **Reset**.

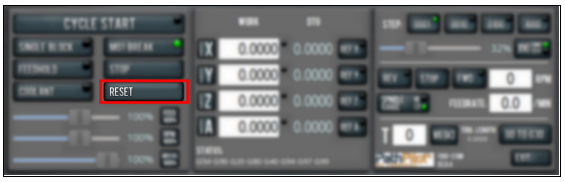


Figure 7-73: Reset button.

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 7-74: Work Offset DRO fields.

For information, see "Jog the Machine" (page 140).

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.

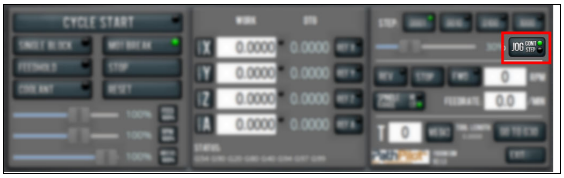


Figure 7-75: Jog button.

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.

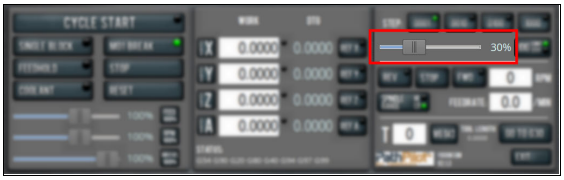


Figure 7-76: Jog Speed slider.

For more information on continuous velocity mode, see "About Continuous Velocity Jogging" (page 141).

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.

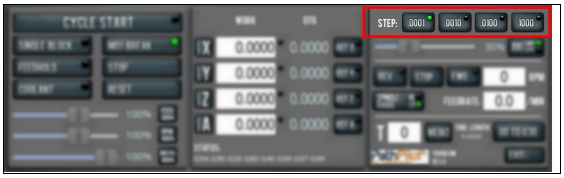


Figure 7-77: Step buttons (in G20 mode).

- 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 141).

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**.

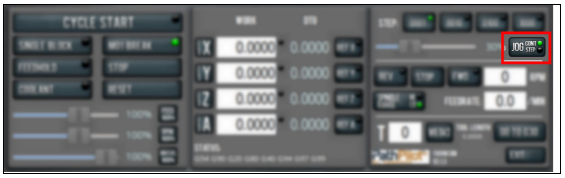


Figure 7-78: Continuous velocity jogging controls.

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 7-79: 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** 0.00025 in. to 0.1000 in.
- **Metric (G21) Mode** 0.010 mm to 2.00 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.

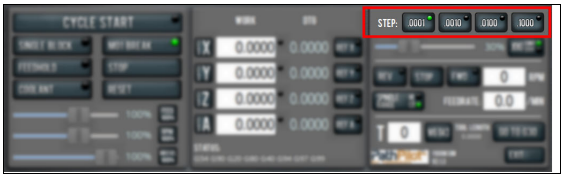


Figure 7-80: Step buttons (in G20 mode).

7.4.4 View the Current Machine Position

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

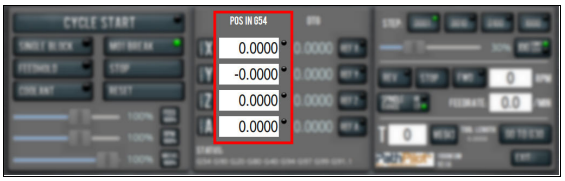


Figure 7-81: Work Offset DRO fields.

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 147).

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**.

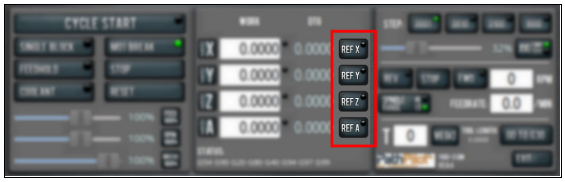


Figure 7-82: Reference buttons.

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 140).

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**.

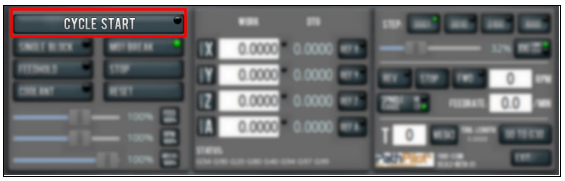


Figure 7-83: Cycle Start button.

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 82).
- Before you've loaded a G-code program. For information, see "Load G-Code" (page 142).
- Before referencing the machine. For information, see "Reference the Machine" (page 140).

7.4.7 Stop Machine Motion

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

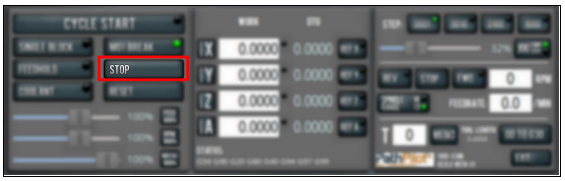


Figure 7-84: Stop button.

7.4.8 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.

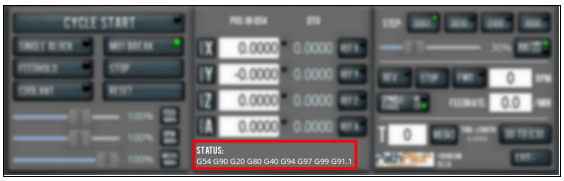


Figure 7-85: Status read-only DRO field.

For more information on G-code modes, go to "View Available G-Code Modes" (page 123).

7.4.9 View the Distance to Go

To view the distance to go:

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

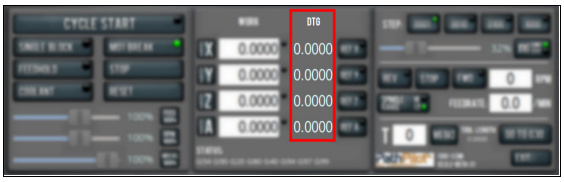


Figure 7-86: DTG read-only DRO fields.

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

- Select **Feed Hold**.

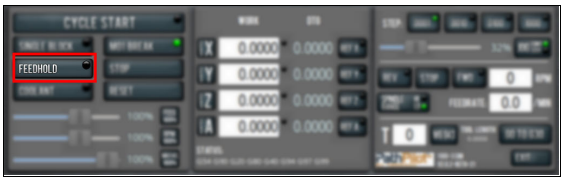


Figure 7-87: Feed Hold button.

> **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.

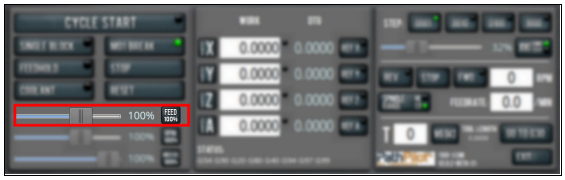


Figure 7-88: Feed Rate Override slider.

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**.

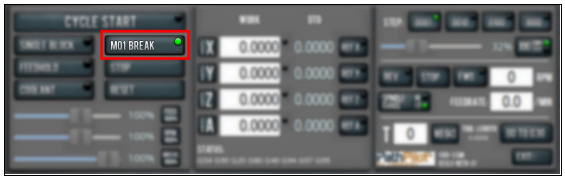


Figure 7-89: M01 Break button.

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 125).
- **When M01 Break is Inactive** PathPilot ignores all programmed M01 commands.

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 7-90: 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**.

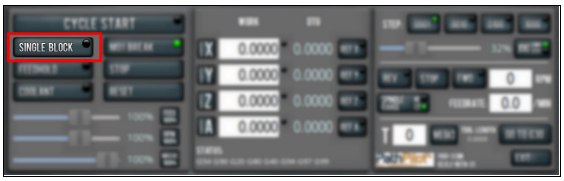


Figure 7-91: Single Block button.

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 125).

You can turn single block mode on or off either before starting a program or while a program is running. For information, see "Use Single Block Mode" (above).

> **Note:** Single block mode ignores non-motion lines, like comment lines or blank lines.

7.5.6 Use the Spindle Override Function

To use the spindle override function:

- Using the **Spindle Override** slider, change the programmed spindle speed by a specific percentage.

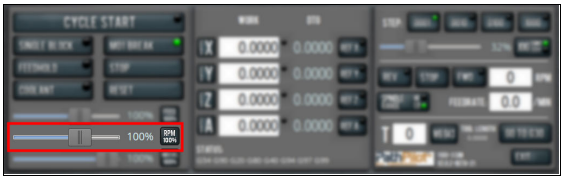


Figure 7-92: Spindle Override slider.

> **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.

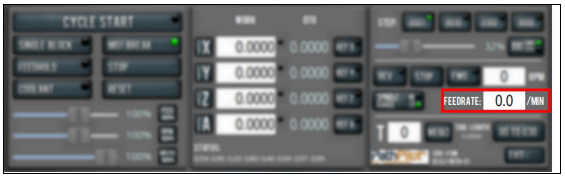


Figure 7-93: Feed Rate DRO field.

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

Motion	Feed Rate
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 7-94: Spindle RPM DRO field.

For information, see "About Spindle Controls" (below).

About Spindle Controls

A spindle speed is the rate at which the spindle rotates.

Button	G-Code	Use to...
FWD	M03	Start the spindle clockwise at the RPM specified in the Spindle RPM DRO field.
Stop	M05	Stop the spindle.

:

- A G-code program is running.
- Using manual data input (MDI) commands.

Spindle Controls Reference

The spindle speed is measured in revolutions per minute (RPM).
The spindle speed range is 10,000 rpm to 24,000 rpm.
Use lower spindle speeds when you're using larger cutting tools; use higher spindle speeds when you're using smaller cutting tools.

7.5.9 Change the Tool Number

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

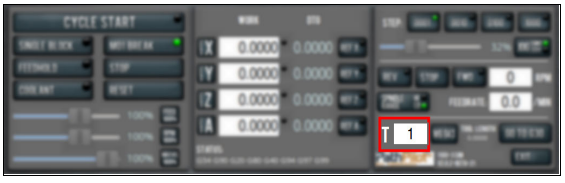


Figure 7-95: Tool DRO field.

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 143). 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**.

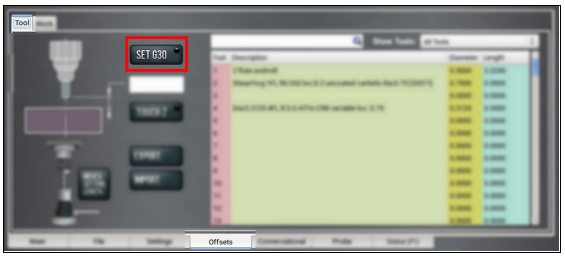


Figure 7-96: Set G30 button.

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**.

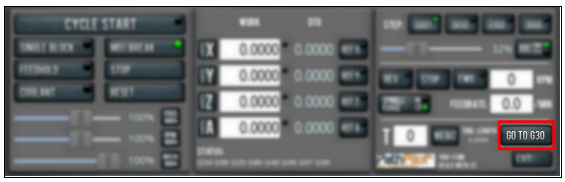


Figure 7-97: Go to G30 button.

> **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 110).

> **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.

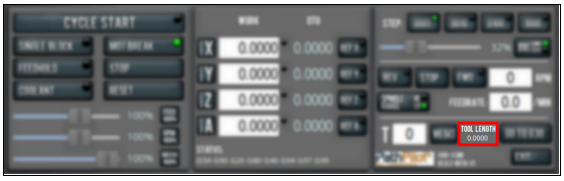


Figure 7-98: Tool Length DRO field.

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.

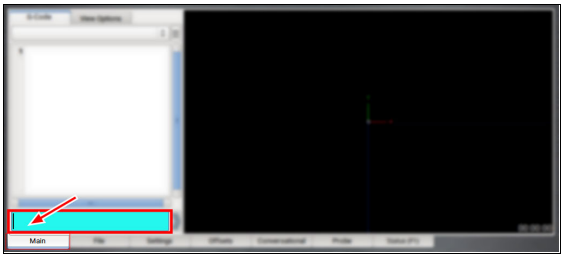


Figure 7-99: MDI Line DRO field.

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 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**.

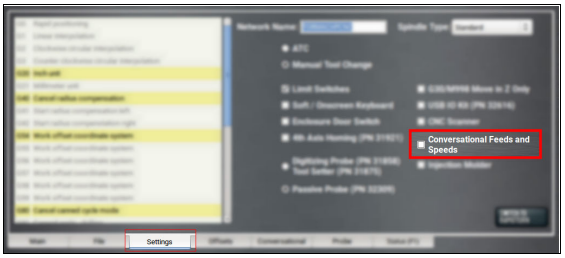


Figure 7-100: Settings tab.

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

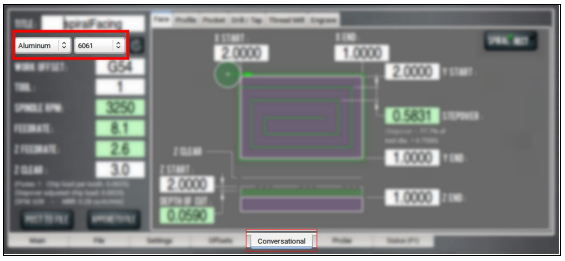


Figure 7-101: Feeds and speeds suggestions on the Conversational tab.

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.

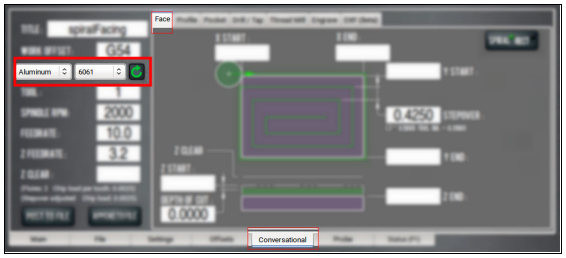


Figure 7-102: Refresh button on the Conversational tab.

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.

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" (on the previous page).

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

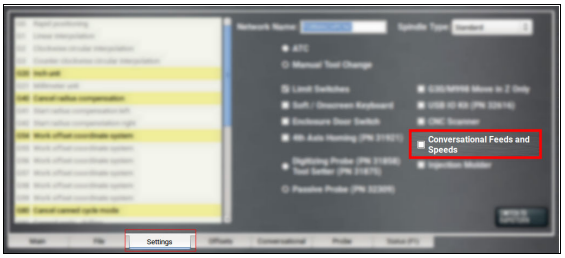


Figure 7-103: Settings tab.

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.

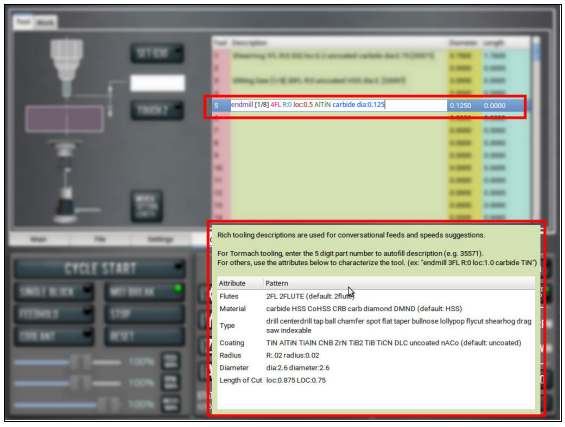


Figure 7-104: A manually-entered tool description.

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.

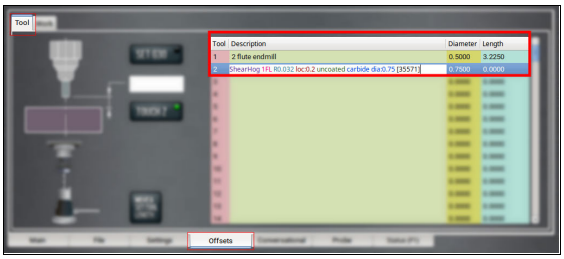


Figure 7-105: An automatically-generated tool description for a Tormach tool.

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

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

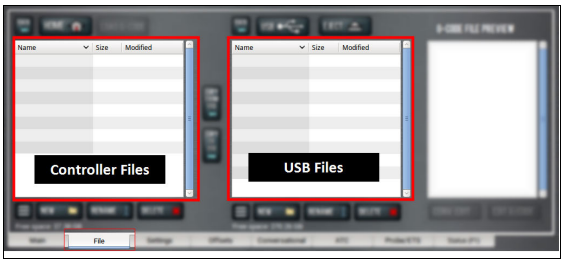


Figure 7-106: File tab.

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 90).

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.

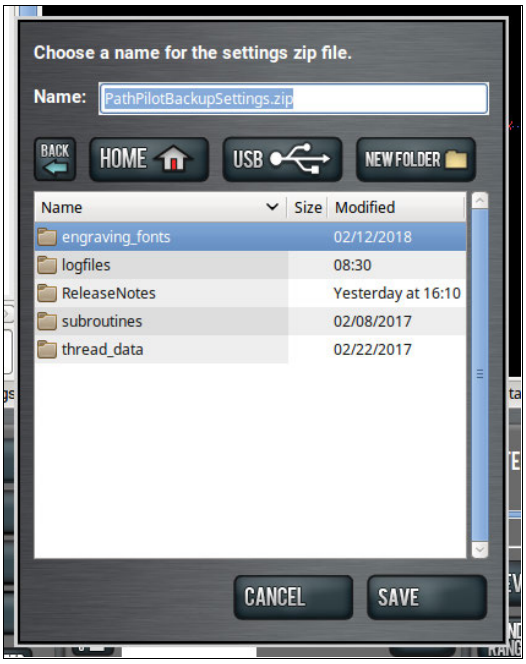


Figure 7-107: Admin Settings Backup dialog box.

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 7-108: 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.

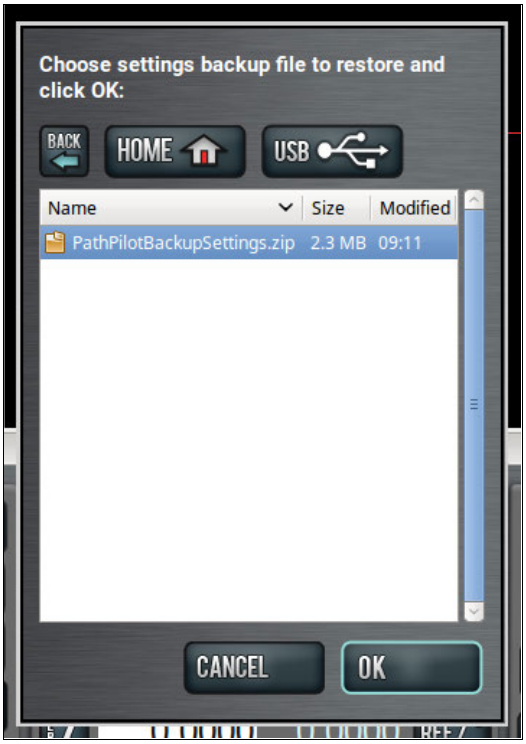


Figure 7-109: Admin Settings Restore dialog box.

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.

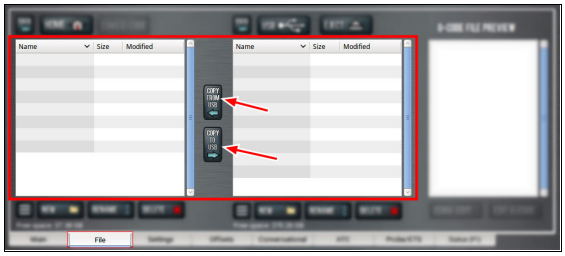


Figure 7-110: USB Files window on the File tab.

> **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.

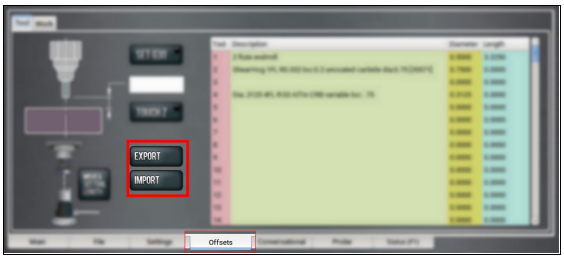


Figure 7-111: Export and Import buttons on the Offsets tab.

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.

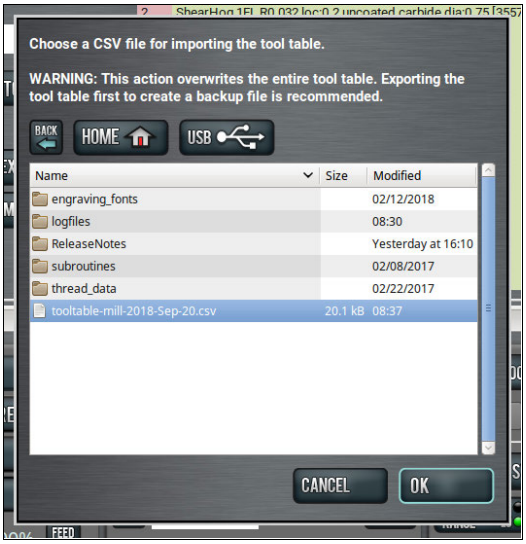


Figure 7-112: Import dialog box.

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.

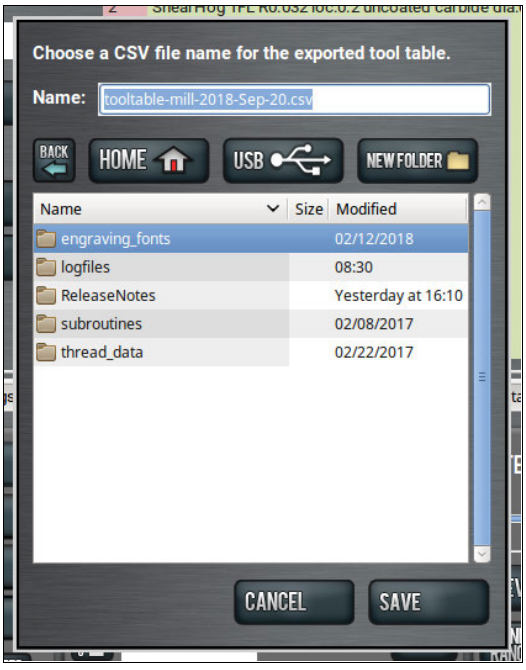


Figure 7-113: Export dialog box.

2. In the **Name** DRO field, type the name for the .csv file.
3. Select **Save**.
   The .csv file is saved in the **File** tab.

4. From the **File** tab, select the newly created .csv file, and then select **Copy to USB**.
5. Select **Eject**.
   It's safe to remove the USB drive from the controller.

BASIC OPERATIONS

IN THIS SECTION, YOU'LL LEARN:

- About the basic operations required for most projects, organized as a suggested project workflow.

CONTENTS

8.1 START THE MACHINE

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**.

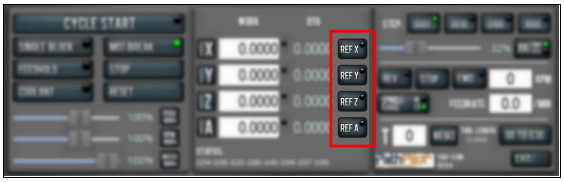


Figure 8-1: Reference buttons.

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" (below).

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.

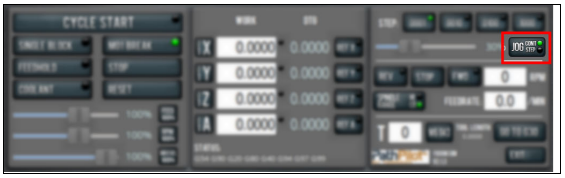


Figure 8-2: Jog button.

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.

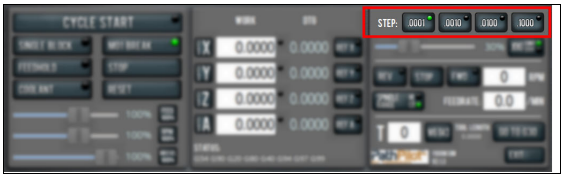


Figure 8-4: Step buttons (in G20 mode).

- 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.

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** 0.00025 in. to 0.1000 in.
- **Metric (G21) Mode** 0.010 mm to 2.00 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. In the **RPM** DRO field, type the desired RPM speed. Then select the **Enter** key.
4. Select **FWD** to start the spindle in the forward direction.
5. Select **Stop** to stop the spindle.

8.4.1 About the Spindle

The machine spindle gives power to the cutting tool, which allows it to remove material from the workpiece. The spindle is driven by the spindle motor.
Operate the spindle either manually or by G-code commands (entered in the MDI Line DRO field or programmed into a G-code program).
The machine's spindle rotates clockwise (forward) at a specified spindle speed.

8.4.2 Spindle Controls Reference

The spindle speed is measured in revolutions per minute (RPM).
The spindle speed range is 10,000 rpm to 24,000 rpm.

Use lower spindle speeds when you're using larger cutting tools; use higher spindle speeds when you're using smaller cutting tools.

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 90).
To load G-code:

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

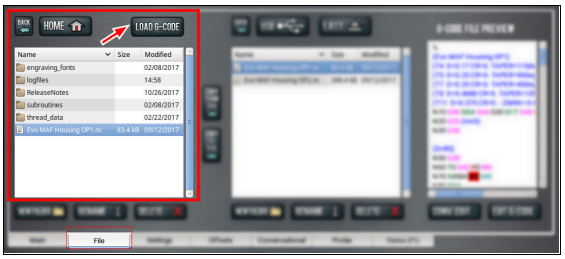


Figure 8-6: Controller Files window on the File tab.

> **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 INSTALL A TOOL IN AN ER COLLET SPINDLE

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 spindle:

1. Hold the collet at an angle, and then insert it into the collet nut as shown in the following image.

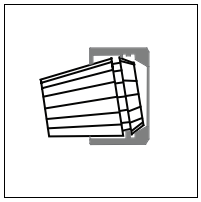


Figure 8-7: A collet inserted into the collet nut.

2. Tilt up the collet to snap it into place.

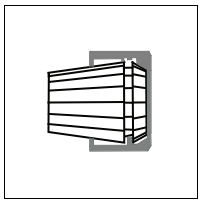


Figure 8-8: The collet tilted into place.

3. Loosely thread the nut on the spindle, insert the tool, and then tighten the collet.

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" (page 147).

> **Note:** You can import a .csv file with tool length offset data. For information, see "Import and Export the Tool Table" (page 137).

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

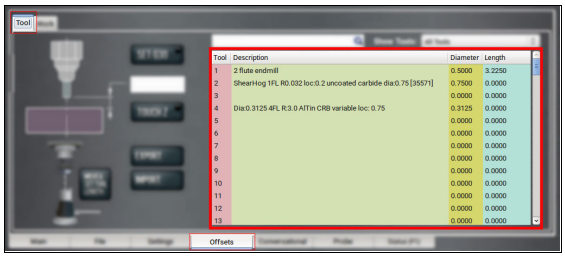


Figure 8-9: Tool Table window on the Offsets tab.

5. Depending on your workflow, you can measure your tools using any of the following methods:

- **Use an Electronic Tool Setter** For information, see "Use an Electronic Tool Setter (ETS) to Measure Tools" (page 117).
- **Touch Off of a Known Reference Height** For information, see "Touch Off the Tool Length Offsets" (page 145).

8.7.1 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.
There are two steps to use an ETS. Complete the following steps in the order listed:

Set up the Electronic Tool Setter (ETS)

There are three steps to set up the ETS. Complete the following steps in the order listed:

Set the ETS Height

Before you begin to use the ETS, you must first use the PathPilot interface to set its work offset.
To set the ETS height:

1. Set a new Z zero position for the currently selected work offset.
   For information, see Set a Known Reference Height.
2. Put the ETS on the known reference height (from Step 1).
3. Jog the spindle until it's over the ETS.

4. From the PathPilot interface, on the **Probe** tab, select the **ETS Setup** tab. Then find the **ETS Work Offset Setup** group, and select **Move & Set ETS Height**.

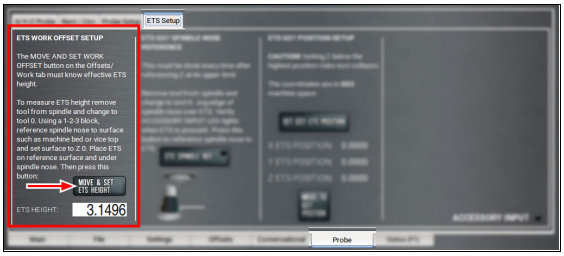


Figure 8-10: Move & Set ETS Height button on the Probe tab.

The Z-axis moves down (-Z) until the spindle nose contacts and triggers the ETS.

5. In the **ETS Height** DRO field, verify that the length of the ETS updated.

Reference the Spindle Nose

Note: You must repeat this procedure after each time that you reference the Z-axis.

1. Identify a home location for your ETS. You can use anywhere within the machine's area of travel as the home location, so long as you can center the spindle above the ETS.

Tip! We recommend putting the ETS toward the Y+ end of travel (where it's outside of the 2 ft × 4 ft standard work envelope, and on the surface of the vacuum table). For information, see "ETS Placement Layout" (page 233).

2. Remove the collet nut and the tool from the spindle.
3. From the PathPilot interface, in the **Tool** DRO field, type `0`. Then select the **Enter** key.
4. Jog the spindle until it's over the ETS. Then, slowly jog the Z-axis down (-Z) toward the contact pad on the ETS.
5. From the PathPilot interface, on the **ETS Setup** tab, find the **ETS G37 Spindle Nose Reference** section, and select **ETS Spindle Ref**.

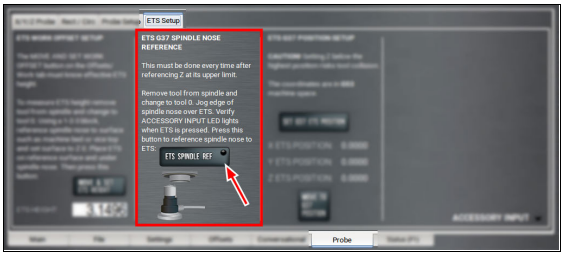


Figure 8-11: ETS Spindle Ref button on the Probe tab.

The Z-axis moves down (-Z) until the spindle nose contacts and triggers the ETS.
The spindle nose is now referenced to the ETS.

Set the G37 Position

1. Remove the collet nut and the tool from the spindle.
2. From the PathPilot interface, in the **Tool** DRO field, type `0`. Then select the **Enter** key.
3. Jog the spindle until it's over the ETS, and center the spindle over its contact pad.
4. Jog the Z-axis up (+Z) until it's at a safe clearance height for your longest tool.

NOTICE! If the Z-axis is set below the highest position, there's a risk of tool collision.

5. From the PathPilot interface, on the **ETS Setup** tab, find the **ETS G37 Position Setup** group, and select **Set G37 ETS Position**.

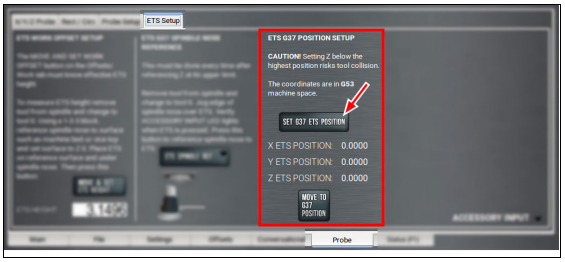


Figure 8-12: Set G37 ETS Position on the Probe tab.

The G37 position is now set.

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

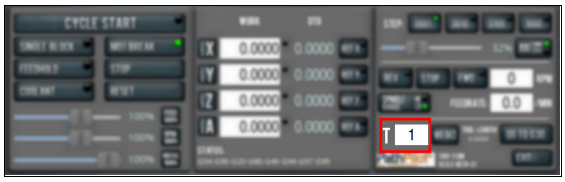
Note: The values displayed in these DRO fields are in G53.

Measure Tools Using an Electronic Tool Setter (ETS)

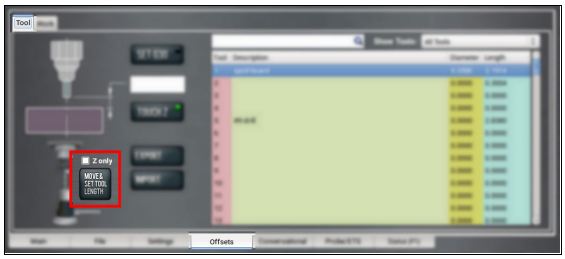
Depending on your workflow, do one of the following:

Manually Measure Tool Lengths (with PathPilot)

1. Plug in the ETS to the **Accessory 2** port.
2. Set up the ETS.
   For information, see "Set up the Electronic Tool Setter (ETS)" (page 143).
3. Put the ETS in its home position (that you determined in "Set up the Electronic Tool Setter (ETS)" (page 143)).
4. From the PathPilot interface, on the **Offsets** tab, in the **Tool Table** window, in the **Description** column, type a description for the tool.
5. In the **Diameter** column, type the diameter of the tool. Then select the **Enter** key.
6. Install a tool into the spindle.
7. From the PathPilot interface, type the tool number in the **Tool** DRO field. Then select the **Enter** key.



8. On the **Offsets** tab, find the **Move and Set Tool Length** button and the **Z only** checkbox. Verify that the checkbox is cleared, and then select **Move and Set Tool Length**.



> **Note:** You should only use the **Z only** checkbox to manually measure tools with a larger diameter. When it's selected, the machine doesn't go to the G37 position — instead, it just moves straight down (Z-) to measure the tool.

The machine moves to the G37 position and measures the tool with the ETS.

> **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.

Automatically Measure Tool Lengths (with G37)

We recommend using the G37 G-code command to measure tools. This method simplifies the tool measurement procedure — you're letting the machine do the work for you — but it also increases tool length accuracy and reduces tool change times in multi-tool programs.
Depending on your workflow, do one of the following:

- **Use G37 in the MDI Line DRO Field**
  1. Set up the ETS.
     For information, see"Set up the Electronic Tool Setter (ETS)" (page 143).
  2. Put the ETS in its home position (that you determined in "Set up the Electronic Tool Setter (ETS)" (page 143)).
  3. Put a tool into the spindle and tighten the collet nut.
  4. From the PathPilot interface, in the **MDI Line** DRO field, type `G37`. Then select the **Enter** key.
     The spindle moves to the ETS position, measures the length of the tool, and applies that length to the currently selected tool in the tool offsets table.
- **Use G37 in a G-Code Program**
  1. Set up the ETS.
     For information, see"Set up the Electronic Tool Setter (ETS)" (page 143).
  2. From the PathPilot interface, load a G-code program with a G37 command.
  3. Select **Cycle Start**.
     When the program reaches the G37 command, the machine moves to the ETS and measures the length of the tool.

For information, see "Programming" (page 149).

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

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 141).

9. From the PathPilot interface, in the **Z-axis** work offset DRO field, type the thickness of the piece of paper. Then select the **Enter** key.

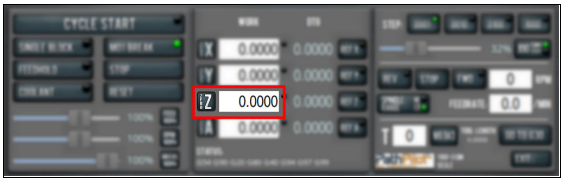


Figure 8-13: Z-axis work offset DRO field.

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

10. To set the tool length offset, go to Measure Tools Using a Known Reference Height.

Measure Tools Using a Known Reference Height

This procedure sets the tool length offset using a known reference height. If you have not yet done so, you must first set the Z zero position; go to Set a Known Reference Height.

To measure tools using a known reference height:

1. Verify that the reference surface is still on the machine table with the piece of paper.
2. From the PathPilot interface, on the **Offsets** tab, find an unused tool number in the **Tool Table** window. Then, type a description for the tool you're measuring.
3. Put the tool holder into the spindle.
4. From the PathPilot interface, in the **Tool** DRO field, type the number of the tool. Then select the **Enter** key.

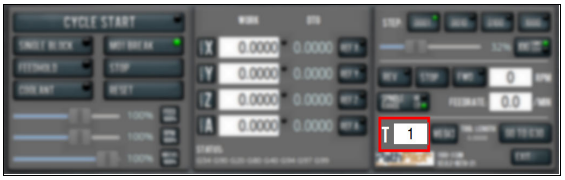


Figure 8-14: Tool DRO field.

5. Slowly jog the Z-axis down (-Z) until it is 0.04 in. (1 mm) from the reference surface.
6. Continue to slowly jog the Z-axis while slowly moving the piece of paper back-and-forth on the reference surface.
7. Stop jogging the Z-axis when you feel a light pull on the piece of paper, which indicates that it is in contact with the tool.
8. From the PathPilot interface, on the **Offsets** tab, in the **Tool Table**, select the tool for which you previously wrote a description.

9. In the **Touch Z** DRO field, type the thickness of the piece of paper. Then select the **Enter** key.

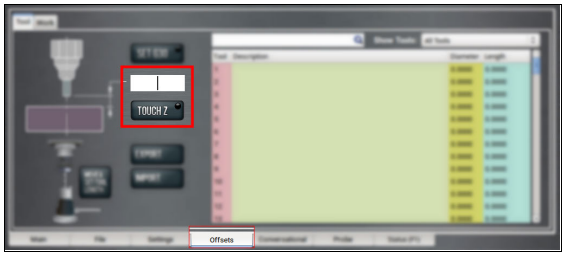


Figure 8-15: Touch Z DRO field and button.

10. Select **Touch Z**.
    The length of the tool is stored in the **Tool Table** window.
11. From the **Tool Table** window, in the **Length** column, verify that the length of the tool is correct.
12. In the **Diameter** column, type the diameter of the tool. Then select the **Enter** key.
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 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 tip of the tool to the spindle nose. Because the ER20 collet spindle doesn't provide a repeatable tool length, the tool length must be measured every time that you remove a tool from the spindle. To speed up tool changes, we recommend using an Electronic Tool Setter (PN 31875) when measuring tool lengths.

Before you begin a G-code program, you must verify the lengths of the tools in the program, and make sure that the lengths agree with the tool length offsets set in PathPilot:

- Each time you change tools, you must apply a new tool length offset in PathPilot.
- Each time you replace a tool, you must remeasure its length, and apply a new tool length offset in PathPilot.

> ***NOTICE!*** You must always verify that the physical length of a tool agrees with the tool length offset value set in PathPilot. If you don't, there's a risk that the tool length offset misrepresents the currently active tool in the spindle, which may result in a machine crash or damaged tooling, workpieces, or fixtures.

8.8 SET WORK OFFSETS

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

➢ Select **Zero [Axis]**.

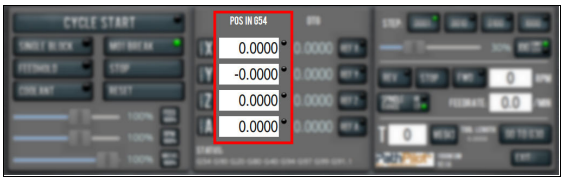


Figure 8-16: Work Offset DRO fields.

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.

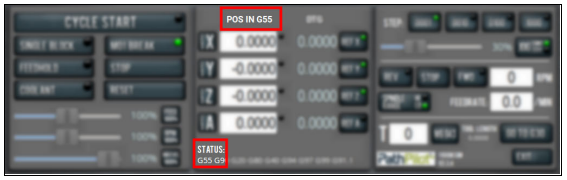


Figure 8-17: Work offset indicated in the PathPilot interface.

> **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" (on the next page).

8.8.1 Set the Z-Axis Work Offset with an Electronic Tool Setter (ETS)

1. Set up the ETS.
   For information, see "Set up the Electronic Tool Setter (ETS)" (page 143).
2. Install a tool into the spindle.
   For information, see Install a Tool in an ER Collet Tool HolderSpindle.
3. Use the ETS to measure the length of the tool in the spindle.
   For information, see "Set Tool Length Offsets" (page 143).
4. Put the ETS on the surface that you want to set as Z zero.
5. Jog the spindle until the tool is centered over the ETS.
6. From the PathPilot interface, on the **Offsets** tab, on the **Work** tab, select **Move and Set Work Offset**.

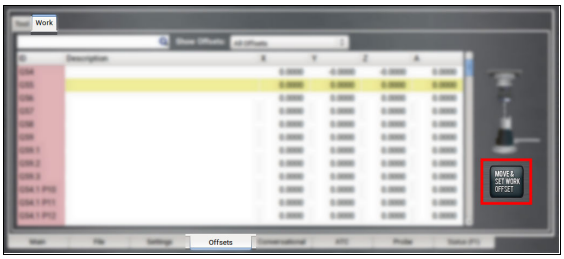


Figure 8-18: Work tab on the Offsets tab.

The machine moves down (-Z) until the tool contacts the ETS. The Z-axis offset updates for the current work offset.

8.8.2 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

PROGRAMMING

IN THIS SECTION, YOU'LL LEARN:

- About the languages that are understood and interpreted by PathPilot.

CONTENTS

9.1 PROGRAMMING OVERVIEW

Read the following sections for a G-code overview:

9.1.1 About G-Code Programming Language

A G-code program is made up of one or more lines of code. Each line of code is called a block, and can include commands to the machine. Blocks are collected into a file, which makes a program.

A block is normally made up of an optional line number at the beginning, followed by one or more words, which groups the elements together into a single statement.

A word is a letter followed by a number (or, something that evaluates to a number). A word can either give a command or provide an argument to a command.

A program is one or more blocks, each separated by a line break. Blocks in a program are executed either:

- Sequentially (from the top of the program to the bottom)
- Until an end command (M02 or M30) is encountered

EXAMPLE:
`G01 X3` is a valid line of code with two words:

- `G01` is a command: the machine should move in a straight line at the programmed feed rate.
- `X3` provides an argument value: the value of X should be 3 at the end of the move.

Most commands start with either G (general) or M (miscellaneous) — G-codes and M-codes.

There are two commands (M02 and M30) that end a program. A program can end before the end of a file. If there are lines in a file after the end of a program, they're not meant to be executed in the normal flow (they're generally parts of subroutines).

9.1.2 G-Code Formatting Reference

A permissible block of input code is made up of the following programming elements, in order, with the restriction that there is a maximum of 256 characters allowed on a line:

1. *(Optional)* Block delete character (`/`)
2. *(Optional)* Line number
3. Any number of words, parameter settings, and comments
4. End of line marker (carriage return or line break)

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.

9.1.3 Supported G-Codes Reference

G-Code	Description
G00	Rapid linear motion
G01	Linear motion at feed rate
G02	Clockwise arc at feed rate
G03	Counterclockwise arc at feed rate
G04	Dwell
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

9.2 PROGRAMMING G-CODE

Read the following sections as a G-code reference:

9.2.1 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.

9.2.2 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

9.2.3 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

9.2.4 Arc at Feed Rate (G02 and G03)

A circular or helical arc is specified using either `G02` (clockwise arc) or `G03` (counterclockwise arc). The axis of the circle or helix must be parallel to the X-, Y- or Z-axis of the machine coordinate system. The axis (or equivalently, the plane perpendicular to the axis) is selected with `G17` (Z-axis, XY-plane), `G18` (Y-axis, XZ-plane) or `G19` (X-axis, YZ-plane). If the arc is circular, it lies in a plane parallel to the selected plane.
If a line of code makes an arc and includes rotational axis motion, the rotational axes turn at a constant rate so that the rotational motion starts and finishes when the XYZ motion starts and finishes. This is rare.
The motion differs if cutter radius compensation is active.
Two formats are allowed for specifying an arc: the center format and the radius format. In both formats, the `G02` or `G03` is optional if it's the current motion mode.

Radius Format Arc

For a clockwise arc in radius format, program: `G02 X~ Y~ Z~ A~ R~`
For a counterclockwise arc in radius format, program: `G03 X~ Y~ Z~ A~ R~`

- `X~` is the X-axis coordinate
- `Y~` is the Y-axis coordinate
- `Z~` is the Z-axis coordinate
- `A~` is the A-axis coordinate
- `R~` is the radius of the arc

In radius format, the coordinates of the end point of the arc in the selected plane are specified along with the radius of the arc. A positive radius indicates that the arc turns through 180 degrees or less, while a negative radius indicates a turn of 180 degrees to 359.999 degrees.
If the arc is helical, the value of the end point of the arc on the coordinate axis parallel to the axis of the helix is also specified.
We don't recommend programming radius format arcs that are:

- Nearly full circles
- Semicircles
- Nearly semicircles

A small change in the location of the end point produces a much larger change in the location of the center of the circle (and the middle of the arc). The magnification effect is large enough that rounding error in a number can produce out-of-tolerance cuts.

You can program arcs that are:

- Up to 165 degrees
- Between 195 degrees to 345 degrees

EXAMPLE

`G17 G02 X 1.0 Y 1.5 R 2.0 Z 0.5` is a radius format command to mill an arc, which makes a clockwise (as viewed from the positive Z-axis) circular or helical arc whose axis is parallel to the Z-axis, ending where X = 1.0, Y = 1.5, and Z = 0.5, with a radius of 2.0. If the starting value of Z is 0.5, this is an arc of a circle parallel to the XY-plane; otherwise, it's a helical arc.

Troubleshooting

It's an error if:

- Both of the axis words for the axes of the selected plane are omitted
  The axis words are all optional except that at least one of the two words for the axes in the selected plane must be used.
- No R word is given
- The end point of the arc is the same as the current point
- `G10`, `G28`, `G30`, or `G92` appear in the same block

Center Format Arc

For a clockwise arc in center format, program: `G02 X~ Y~ Z~ I~ J~`

For a counterclockwise arc in center format, program: `G03 X~ Y~ Z~ I~ J~`

- `X~` is the X-axis coordinate
- `Y~` is the Y-axis coordinate
- `Z~` is the Z-axis coordinate
- `A~` is the A-axis coordinate
- `I~` is the center of arc (X coordinate)
- `J~` is the center of arc (Y coordinate)
- `K~` is the center of arc (Z coordinate)

In the center format, the coordinates of the end point of the arc in the selected plane are specified along with the offsets of the center of the arc from the current location. In this format, it's okay if the end point of the arc is the same as the current point.

The center is specified using the I, J, K words associated with the active plane. These specify the center relative to the current point at the start of the arc, defined in incremental coordinates from the start point.

It's an error if:

- When the arc is projected on the selected plane, the distance from the current point to the center differs from the distance from the end point to the center by more than 0.0002 inches (if you're programming in inches) or 0.002 millimeters (if you're programming in millimeters)
- `G10`, `G28`, `G30`, or `G92` appear in the same block

Arc in XY Plane

When the XY-plane is selected, program: `G02 X~ Y~ Z~ A~ I~ J~` (or, use `G03` instead of `G02`)

I and J are the offsets from the current location or coordinates – depending on arc distance mode (G90.1/G91.1) of the center of the circle (X and Y directions, respectively).

It's an error if:

- X and Y are both omitted
  The axis words are all optional except that at least one of X and Y must be used.
- I and J are both omitted
  I and J are optional except that at least one of the two must be used.

Arc in XZ Plane

When the XZ-plane is selected, program: `G02 X~ Y~ Z~ A~ I~ K~` (or, use `G03` instead of `G02`)

I and K are the offsets from the current location or coordinates – depending on arc distance mode (G90.1/G91.1) of the center of the circle (X and Z directions, respectively).

It's an error if:

- X and Z are both omitted
  The axis words are all optional except that at least one of X and Z must be used.
- I and K are both omitted
  I and K are optional except that at least one of the two must be used.

Arc in YZ Plane

When the YZ-plane is selected, program: `G02 X~ Y~ Z~ A~ J~ K~` (or, use `G03` instead of `G02`)

J and K are the offsets from the current location or coordinates – depending on depending on arc distance mode

(G90.1/G91.1) of the center of the circle (Y and Z directions, respectively).
It's an error if:

- Y and Z are both omitted
  The axis words are all optional except that at least one of Y and Z must be used.
- J and K are both omitted
  J and K are optional except that at least one of the two must be used.

EXAMPLE
`G17 G02 X1.0 Y1.6 I0.3 J0.4 Z0.9` is a center format command to mill an arc in incremental arc distance mode (G91.1) that makes a clockwise (as viewed from the positive Z-axis), circular, or helical arc whose axis is parallel to the Z-axis, ending where X = 1.0, Y = 1.6, and Z = 0.9, with its center offset in the X direction by 0.3 units from the current X location and offset in the Y direction by 0.4 units from the current Y location. If the current location has X = 0.7, Y = 0.7 at the outset, the center is at X = 1.0, Y = 1.1. If the starting value of Z is 0.9, this is a circular arc; otherwise, it's a helical arc. The radius of this arc would be 0.5.

In the center format, the radius of the arc is not specified, but it may be found easily as the distance from the center of the circle to either the current point or the end point of the arc.

```
(Sample Program G02EX3:)
(Workpiece Size: X4, Y3, Z1)
(Tool: Tool #2, 1/4” Slot Drill)
(Tool Start Position: X0, Y0, Z1)
N2 G90 G80 G40 G54 G20 G17 G94 G64 (SAFETY BLOCK)
N5 G90 G20
N10 M06 T2 G43 H2
N15 M03 S1200
N20 G00 X1 Y1
N25 Z0.1
N30 G01 Z-0.1 F5
N35 G02 X2 Y2 I1 J0 F20 (ARC FEED CW, RADIUS I1,J0
AT 20 IPM)
N40 G01 X3.5
N45 G02 X3 Y0.5 R2 (ARC FEED CW, RADIUS 2)
N50 X1 Y1 R2 (ARC FEED CW, RADIUS 2)
N55 G00 Z0.1
N60 X2 Y1.5
N65 G01 Z-0.25
N70 G02 X2 Y1.5 I0.25 J-0.25 (FULL CIRCLE ARC FEED
MOVE CW)
N75 G00 Z1
N80 X0 Y0
N85 M05
N90 M30
```

9.2.5 Dwell (G04)

For a dwell, program: `G04 P~`

- `P~` is the dwell time (measured in seconds)

Dwell keeps the axes unmoving for the period of time in seconds specified by the P number.

EXAMPLE
`G04 P4.2` (to wait 4.2 seconds)

Troubleshooting

It's an error if:

- The P number is negative

9.2.6 Set Offsets (G10)

Use the controls on the Offsets tab to set offsets. You can program offsets with the `G10` G-code command.
Read the following sections for reference:

Set Tool Table (G10 L1)

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

9.2.7 Plane Selection (G17, G18, G19)

To select the XY-plane as active, program: `G17`
To select the XZ-plane as active, program: `G18`
To select the YZ-plane as active, program: `G19`
The active plane determines how the tool path of an arc (`G02` or `G03`) or canned cycle (`G73`, `G81` through `G89`) is interpreted.

9.2.8 Length Units (G20 and G21)

To set length units to inches, program: `G20`
To set length units to millimeters, program: `G21`

> **Tip!** Program either `G20` or `G21` near the beginning of a program, before any motion occurs. Avoid using either one anywhere else in the program. It's your responsibility to make sure that all numbers are appropriate for use with the current length units.

9.2.9 Return to Predefined Position (G28 and G28.1)

To make a rapid linear move from the current position to the absolute position of the values in parameters 5161-5166: `G28`
To make a rapid linear move to the G28.1 position by first going to the intermediate position specified by the X~, 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

9.2.10 Return to Predefined Position (G30 and G30.1)

G30 uses the values stored in parameters 5181 and 5183 as the X and Z final point to move to. The parameter values are absolute machine coordinates in the native machine units of inches.
To make a rapid traverse move from the current position to the absolute position of the values in parameters, program: `G30`
To make a rapid traverse move to the position specified by axes including any offsets, then make a rapid traverse move to the absolute position of the values in parameters 5181 and/or 5183, program: `G30 X~ Z~`

> **Note:** Any axis not specified won't move.

To store the current absolute position into parameters 5181-5183, program: `G30.1`

Troubleshooting

It's an error if:

- Cutter Compensation is turned on

9.2.11 Automatically Measure Tool Lengths with an ETS (G37 and G37.1)

Use G37 and G37.1 with an Electronic Tool Setter (ETS) to enable automatic length measurement. For automated use, add a G37 command after an M6 tool change commands.
If you're using the ETS with a mill, the input port varies depending on your machine:

- **M Series Mills** Plug the ETS into the Accessory Input 2 port. You can still use the Accessory Input 1 port for other probes and accessories.
- **Older PCNC Mills** Plug the ETS into the (single) accessory input port.

Move to G37 Position Over ETS (G37.1)

To move to the G37 position (over the ETS), program: `G37.1`
To set the G37 position:

1. Jog the machine over the center of the ETS.
2. From the **Probe** tab, on the **ETS Setup** tab, select **Set G37 ETS Position**.
   The read-only DROs in the **ETS G37 Position Setup** group display the new position.

The G37 position is in G53 machine coordinate space. It defaults to (0, 0, 0), or the top left rear of machine travel (the same as the X-, Y-, and Z-axis reference position).
G37.1 supports X and Y tool offsets. If there are X or Y tool offsets present in the tool table (manually applied through a G10 L1 command), they offset the spindle position. This enables G37 for tools mounted in an auxiliary spindle installed on the spindle column.

> **Note:** If G10 L1 is used to change the X or Y offset of the currently loaded tool, you must then apply the new offsets with a G43 command.

G37.1 performs as follows:

1. A rapid upward move to the Z clear position (which is always G53 Z = 0.0).
2. A rapid move in X and Y to the X and Y ETS coordinates.
3. A rapid downward move in Z to the Z ETS coordinate.

> **Note:** The Z word saves time by rapidly moving closer to the ETS before the slower probing begins. You must use caution if you set this lower than G53 Z = 0.0. If you don't, there's a risk that a long tool could collide with the ETS and damage it and the tool.

Move and Measure Tool Length (G37)

To move and measure the tool length, program: `G37 H~ P~`

- `H~` saves the measured tool length to the H tool table entry instead of the current tool number's entry.
  You could use this to track tool wear between the two tool table entries, for example.

  > **Note:** The newly measured tool length isn't applied, but it's stored in the tool table entry for tool number H.

- `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.

9.2.12 Straight Probe (G38.x)

`G38.2` probes toward the workpiece, stops on contact, and signals error if failure
`G38.3` probes toward the workpiece and stops on contact
`G38.4` probes away from the workpiece, stops on loss of contact, and signals error if failure
`G38.5` probes away from the workpiece and stops on loss of contact
`G38.6` moves away from the workpiece and ignores probe input
To perform a straight probe operation program: `G31 X~ 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
```

9.2.13 Cutter Compensation (G40, G41, G42)

To turn Cutter Compensation off, program: `G40`
It's okay to turn compensation off when it is already off.
It's an error if:

- A G02/G03 arc move is programmed next after a G40
- The linear move after turning compensation off is less than twice the tool tip radius

To program Cutter Compensation to the left of the programmed tool path (as viewed looking down on the machine), program: G41 D~
To program Cutter Compensation to the right of the programmed tool path (as viewed looking down on the machine), program: G42 D~

- D~ is the tool number associated with the diameter offset to be applied

The D word is optional — if there is no D word, the radius of the currently loaded tool is used. If no tool is loaded and no D word is given, a radius of 0 is used. If supplied, the D word is the tool number to use.
The lead in move must be at least as long as the tool radius.
The lead in move can be a rapid move.
It's an error if:

- The D number is not a valid tool number, or it's 0
- Cutter Compensation is commanded to turn on when it is already on

9.2.14 Dynamic Cutter Compensation (G41.1 and G42.1)

To program dynamic Cutter Compensation to the left of the programmed tool path, program: G41.1 D~
To program dynamic Cutter Compensation to the right of the programmed tool path, program: G42.1 D~

- D~ is the tip radius multiplied by two

G41.1 and G42.1 function the same as G41 and G42, with the added scope of being able to ignore the tool table and to program the tool diameter.

Troubleshooting

It's an error if:

- Cutter Compensation is commanded to turn on when it is already on

9.2.15 Apply Tool Length Offset (G43)

To apply a tool length offset from a stored value in the tool table, program: G43 H~

- H~ is the tool number associated with the length offset to be applied.

> **Note:** Generally speaking, the value of the H~ word should match the active tool number (T~ word).

It's okay to program using the same offset already in use, or to program without a tool length offset (if none is currently being used).

Troubleshooting

It's an error if:

- The H number is not an integer
- The H number is negative
- The H number is not a valid tool number

9.2.16 Engrave Sequential Serial Number (G47)

To engrave a serial number, either alone or added to the end of any text, program: Z~ R~ X~ Y~ P~ Q~ D~

- Z~ is the depth of cut of the engraving
- R~ is the retract height between character segments in the numbers
- X~ is, if present, the starting X position, or the left side of the serial number
  If omitted, the current X position is assumed.
- Y~ is, if present, the starting Y position, or the bottom side of the serial number
  If omitted, the current Y position is assumed.
- P~ is, if present, the X extent (width) in current units (inches or millimeters) of the engraved number
- Q~ is, if present, the Y extent (height) in current units (inches or millimeters) of the engraved number
- D~ is, if present, the requested number of decimals of the engraved number
  If the requested D value exceeds the number of decimals in the serial number, the serial number will show leading zeros. If the requested D value is less than the number of decimals in the serial number, only the digits of the serial number will show.

> **EXAMPLE**
> A serial number of 10, where D = 4, engraves as 0010. A serial number of 9056, where D = 3, engraves as 9056.

Troubleshooting

It's an error if:

- Cutter Compensation is on
- The Z number is unspecified
- The R number is unspecified
- The Z number is greater than the R number
- The P number is too small (determined by the font used)
- The Q number is too small (determined by the font used)

9.2.17 Cancel Tool Length Compensation (G49)

To cancel tool length compensation, program: `G49`

9.2.18 Absolute Coordinates (G53)

For rapid linear motion to a point expressed in absolute coordinates, program: `G01 G53 X~ Y~ Z~` (or use with `G00` instead of `G01`)
All the axis words are optional, except that at least one must be used. The `G00` or `G01` is optional if it is in the current motion mode. `G53` isn't modal, and must be programmed on each line on which it is intended to be active. This produces coordinated linear motion to the programmed point. If `G01` is active, the speed of motion is the current feed rate (or slower if the machine won't go that fast). If `G00` is active, the speed of motion is the current traverse rate (or slower if the machine won't go that fast).

Troubleshooting

It's an error if:

- `G53` is used without `G00` or `G01` being active
- `G53` is used while cutter radius compensation is on

9.2.19 Select Work Offset Coordinate System (G54 to G54.1 P500)

You can save up to 500 work offsets in PathPilot. The naming structure varies based on the offset number.

- To select work offset 1, program: `G54` or `G54.1 P1`
- To select work offset 2, program: `G55` or `G54.1 P2`
- To select work offset 3, program: `G56` or `G54.1 P3`
- To select work offset 4, program: `G57` or `G54.1 P4`
- To select work offset 5, program: `G58` or `G54.1 P5`
- To select work offset 6, program: `G59` or `G54.1 P6`
- To select work offset 7, program: `G59.1` or `G54.1 P7`
- To select work offset 8, program: `G59.2` or `G54.1 P8`
- To select work offset 9, program: `G59.3` or `G54.1 P9`
- To select a work offset beyond the standard 9 (listed above), program: `G54.1 P###`, where `P###` is a parameter indicating the index of the work offset you want to use (work offset 10 through work offset 500).

> **EXAMPLE**
> To select the 124th work offset, program `G54.1 P124`.

For information, see "About Work Offsets" (page 148).

Troubleshooting

It's an error if:

- One of these G-codes is used while cutter radius compensation is on
- The X- and Z-axis work offset values are stored in parameters corresponding to the system in use (i.e., System 1 X=5221, Z=5223; System 2 X=5141, Z=5143; up to System 9 X= 5381, Z = 5383).

9.2.20 Set Exact Path Control Mode (G61)

To put the machining system into exact path mode, program: `G61`

9.2.21 Set Blended Path Control Mode (G64)

To attempt to maintain the defined feed velocity, program: `G64 P~ Q~`

- `P~` is, if present, the maximum acceptable tool path deviation to round corners to maintain speed.
  If P is omitted then the speed is maintained however far from the programmed path the tool cuts.
- `Q~` is, if present, the maximum deviation from collinearity that will collapse a series of linear G01 moves at the same feed rate into a single linear move.

It's okay to program for the mode that is already active.

9.2.22 Distance Mode (G90 and G91)

Interpretation of the operating system code can be in one of two distance modes: absolute or incremental.
To go into absolute distance mode, program: `G90`.
In absolute distance mode, axis numbers (X, Y, Z, A) usually represent positions in terms of the currently active coordinate system. Any exceptions to that rule are described explicitly in this section.
To go into incremental distance mode, program: `G91`.

In incremental distance mode, axis numbers (X, Y, Z, A) usually represent increments from the current values of the numbers. I and J numbers always represent increments, regardless of the distance mode setting. K numbers represent increments.

9.2.23 Arc Distance Mode (G90.1 and G91.1)

`G90.1` – Absolute distance mode for I and K offsets. When `G90.1` is in effect, I and K both must be specified with `G02`/`G03` for the XZ plane or it is an error.
`G91.1` – Incremental distance mode for I and K offsets. `G91.1` returns I and K to their default behavior.

9.2.24 Temporary Work Offsets (G92, G92.1, G92.2, and G92.3)

IMPORTANT! This is a legacy feature. Most modern programming methods don't use temporary work offsets.

To apply a temporary work offset, program: `G92 X~ Y~ Z~ A~`

- `X~` is the X-axis coordinate
- `Y~` is the Y-axis coordinate
- `Z~` is the Z-axis coordinate
- `A~` is the A-axis coordinate

`G92` reassigns the current controlled point to the coordinates specified by the axis words (X~, Y~, Z~, and/or A~). No motion takes place.
The axis words are optional, except that at least one must be used. If an axis word is not used for a given axis, the coordinate on that axis of the current point is not changed.
Incremental distance mode (G91) has no effect on the action of `G92`.
When `G92` is executed, it is applied to the origins of all coordinate systems (`G54` through `G59.3`).

EXAMPLE
If the current controlled point is at X = 4, and there is currently no G92 offset active, and then `G92 X7` is programmed, this reassigns the current controlled point to X = 7 — effectively moving the origin of the active coordinate system -3 units in X. The origins of all inactive coordinate systems also move -3 units in X. This -3 is saved in parameter 5211.

`G92` offsets may be already be in effect when the `G92` is called. If this is the case, the offset is replaced with a new offset that makes the current point become the specified value.
It's an error if:

- All axis words are omitted

PathPilot stores the `G92` offsets and reuses them on the next run of a program. To prevent this, you can program a `G92.1` (to erase them), or program a `G92.2` (to stop them being applied – they are still stored).
To reset axis offsets to zero and sets parameters 5211 - 5219 to zero, program: `G92.1`
To reset axis offsets to zero, program: `G92.2`
To set the axis offset to the values saved in parameters 5211 to 5219, program: `G92.3`

9.2.25 Feed Rate Mode (G93, G94, and G95)

To set the active feed rate mode to inverse time, program: `G93`
Inverse time is used to program simultaneous coordinated linear and coordinated rotary motion. In inverse time feed rate mode, an F word means the move should be completed in ***[1/F number]*** minutes.

EXAMPLE
If the F number is 2.0, the move should be completed in half a minute.

When the inverse time feed rate mode is active, an F word must appear on every line which has a `G01`, `G02`, or `G03` motion, and an F word on a line that does not have `G01`, `G02`, or `G03` is ignored. Being in inverse time feed rate mode does not affect `G00` (rapid traverse) motions.
To set the active feed rate mode to units per minute mode, program: `G94`
In units per minute feed rate mode, an F word is interpreted to mean the controlled point should move at a certain number of inches per minute, or millimeters per minute, depending upon what length units are being used.
To set the active feed rate mode to units per revolution mode, program: `G95`
In units per revolution mode, an F word is interpreted to mean the controlled point should move a certain number of inches per revolution of the spindle, depending on what length units are being used. G95 is not suitable for threading, for threading use `G33` or `G76`.

Troubleshooting

It's an error if:

- Inverse time feed rate mode is active and a line with `G01`, `G02`, or `G03` (explicitly or implicitly) does not have an F word
- A new feed rate is not specified after switching to `G94` or `G95` canned cycle return level – `G98` and `G99`

9.2.26 Spindle Control Mode (G96 and G97)

To set constant surface speed mode, program: `G96 D~ S~`

- `D~` is the maximum spindle RPM.
  This word is optional.
- `S~` is the surface speed.

> **Note:** If `G20` is the active mode, the value is interpreted as feet per minute. If `G21` is the active mode, the value is interpreted as meters per minute

> **EXAMPLE**
> `G96 D2500 S250` (set constant surface speed with a maximum RPM of 2500, and a surface speed of 250).

When using `G96` (the most common mode of machine operation), X0 in the current coordinate system (including offsets and tool lengths) must be the spindle axis.
To set RPM mode, program: `G97`

Troubleshooting

It's an error if:

- S is not specified with `G96`
- A feed move is specified in `G96` mode while the spindle is not turning

9.3 PROGRAMMING CANNED CYCLES

Read the following sections for reference:

9.3.1 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.

9.3.2 High Speed Peck Drill (G73)

The `G73` cycle is intended for deep drilling with chip breaking. The retracts in this cycle break the chip but do not totally retract the drill from the hole. It's suitable for tools with long flutes which clear the broken chips from the hole.

Program: `G73 X~ Z~ R~ L~ Q~`

- `Q~` is the delta increment along the Z-axis

The `G73` cycle is as follows:

- **Step 1:** Preliminary canned cycle motion.
- **Step 2:** Move the Z-axis only at the current feed rate downward by delta or to the Z position (whichever is less deep).
- **Step 3:** Rapid back incrementally in Z 0.010 in.
- **Step 4:** Repeat Step 1 through 3 until the Z position is reached at Step 1.
- **Step 5:** Rapid back down to the current hole bottom, backed off a bit.
- **Step 6:** Retract the Z-axis at traverse rate to clear Z.

Troubleshooting

It's an error if:

- The Q number is negative or zero
- The R number is not specified

9.3.3 Cancel Canned Cycles (G80)

To cancels all canned cycles, program: `G80`
It's okay to program `G80` if no canned cycles are in effect.
After a `G80`, the motion mode must be set with `G00` (or any other motion mode G word). If motion mode is not set after `G80`, this error message appears: "**Cannot use axis values without a g code that uses them.**"

9.3.4 Drilling Cycle (G81)

The G81 cycle is intended for drilling.
Program: `G81 X~ Y~ Z~ A~ R~ L~`
The `G81` Cycle is as follows:

- **Step 1:** Preliminary canned cycle motion.
- **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- **Step 3:** Retract the Z-axis at traverse rate to clear Z.

Examples

These examples demonstrate how the `G81` canned cycle works in detail. Other canned cycles work in a similar manner.

EXAMPLE

The current position is (1, 2, 3), the XY-plane has been selected, and the following line of code is interpreted: `G90 G81 G98 X4 Y5 Z1.5 R2.8`
This means that it's in absolute distance mode (G90), old Z retract mode (G98) and the G81 drilling cycle is performed once. The X number and X position are 4. The Y number and Y position are 5. The Z number and Z position are 1.5. The R number and clear Z are 2.8. The following moves take place:

1. G00 motion parallel to the XY-plane to (4,5,3)
2. G00 motion parallel to the Z-axis to (4,5,2.8)
3. G01 motion parallel to the Z-axis to (4,5,1.5)
4. G00 motion parallel to the Z-axis to (4,5,3)

EXAMPLE

The current position is (1, 2, 3), the XY-plane has been selected, the following line of code is interpreted: `G91 G81 G98 X4 Y5 Z-0.6 R1.8 L3`
This means that it's in incremental distance mode (G91), old Z retract mode, and the G81 drilling cycle is repeated three times. The X number is 4, the Y number is 5, the Z number is -0.6 and the R number is 1.8. The initial X position is 5 (=1+4), the initial Y position is 7 (=2+5), the clear Z position is 4.8 (=1.8+3) and the Z position is 4.2 (=4.8-0.6). Old Z is 3.0.
The first move is a traverse along the Z-axis to (1,2,4.8), since old Z < clear Z.
The first repeat consists of three moves:

1. G00 motion parallel to the XY-plane to (5,7,4.8)
2. G01 motion parallel to the Z-axis to (5,7, 4.2)
3. G00 motion parallel to the Z-axis to (5,7,4.8)

The second repeat consists of three moves. The X position is reset to 9 (=5+4) and the Y position to 12 (=7+5):

1. G00 motion parallel to the XY-plane to (9,12,4.8)
2. G01 motion parallel to the Z-axis to (9,12, 4.2)
3. G00 motion parallel to the Z-axis to (9,12,4.8)

The third repeat consists of three moves. The X position is reset to 13 (=9+4) and the Y position to 17 (=12+5):

1. G00 motion parallel to the XY-plane to (13,17,4.8)
2. G01 motion parallel to the Z-axis to (13,17, 4.2)
3. G00 motion parallel to the Z-axis to (13,17,4.8)

```
Example code using G81 cycle:
(Sample Program G81EX18:)
(Workpiece Size: X4, Y3, Z1)
(Tool: Tool #6, 3/4” HSS DRILL)
(Tool Start Position: X0, Y0, Z1)
N2 G90 G80 G40 G54 G20 G17 G94 G64 (Safety Block)
N5 G90 G80 G20
N10 M06 T6 G43 H6
N15 M03 S1300
N20 G00 X1 Y1
N25 Z0.5
N30 G81 Z-0.25 R0.125 F5 (Drill Cycle Invoked)
N35 X2
N40 X3
N45 Y2
```

```
N50 X2
N55 X1
N60 G80 G00 Z1 (Cancel Canned Cycles)
N65 X0 Y0
N70 M05
N75 M30
```

9.3.5 Simple Drilling Cycle (G82)

The G82 cycle is intended for drilling.
Program: `G82 X~ Y~ Z~ A~ R~ L~ P~`
The G82 cycle is as follows:

- **Step 1:** Preliminary canned cycle motion.
- **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- **Step 3:** Dwell for the P number of seconds.
- **Step 4:** Dwell for the P number of seconds.

9.3.6 Peck Drilling Cycle (G83)

The `G83` cycle (often called peck drilling) is intended for deep drilling or milling with chip breaking. The retracts in this cycle clear the hole of chips and cut off any long stringers (which are common when drilling in aluminum).
Program: `G83 X~ Y~ Z~ A~ R~ L~ Q~`

- `Q~` is a delta increment along the Z-axis

The G83 cycle is as follows:

- **Step 1:** Preliminary canned cycle motion.
- **Step 2:** Move the Z-axis only at the current feed rate downward by delta or to the Z position, whichever is less deep.
- **Step 3:** Rapid back out to the clear Z.
- **Step 4:** Repeat Steps 1 through 3 until the Z position is reached at Step 1.
- **Step 5:** Rapid back down to the current hole bottom, backed off a bit.
- **Step 6:** Retract the Z-axis at traverse rate to clear Z.

Troubleshooting

It's an error if:

- The Q number is negative or zero

9.3.7 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.

9.3.8 Boring Cycle (G86)

The `G86` cycle is intended for boring. This cycle uses a P number for the number of seconds to dwell.
Program: `G86 X~ Y~ Z~ A~ R~ L~ P~`
The G86 cycle is as follows:

- **Step 1:** Preliminary canned cycle motion.
- **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- **Step 3:** Dwell for the P number of seconds.
- **Step 4:** Stop the spindle turning.
- **Step 5:** Retract the Z-axis at traverse rate to clear Z.
- **Step 6:** Restart the spindle in the direction it was going.
- **Step 7:** Move the Z-axis only at the current feed rate to the Z position.

Troubleshooting

It's an error if:

- The spindle is not turning before this cycle is executed

9.3.9 Boring Cycle (G88)

The `G88` cycle is intended for boring and uses a P word, where P specifies the number of seconds to dwell.
Program: `G88 X~ Y~ Z~ A~ R~ L~ P~`
The G88 cycle is as follows:

- **Step 1:** Preliminary canned cycle motion.
- **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- **Step 3:** Dwell for the P number of seconds.
- **Step 4:** Stop the spindle turning.
- **Step 5:** Stop the program so the operator can retract the spindle manually.
- **Step 6:** Restart the spindle in the direction it was going.

9.3.10 Boring Cycle (G89)

The `G89` cycle is intended for boring. This cycle uses a P number, where P specifies the number of seconds to dwell.
Program: `G89 X~ Y~ Z~ A~ R~ L~ P~`

The G89 cycle is as follows:

- **Step 1:** Preliminary canned cycle motion.
- **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- **Step 3:** Dwell for the P number of seconds.
- **Step 4:** Retract the Z-axis at the current feed rate to clear Z.

9.4 PROGRAMMING M-CODE

Read the following sections for reference:

9.4.1 Supported M-Codes Reference

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
M27	Dust shoe lift
M28	Dust shoe lower
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

9.4.2 Program Stop and Program End (M00, M01, M02, and M30)

To stop a running program temporarily, regardless of the optional stop switch setting, program: M00
To stop a running program temporarily, but only if the optional stop switch is on, program: M01
It's okay to program M00 and M01 in MDI mode, but the effect probably won't be noticeable because normal behavior in MDI mode is to stop after each line of input.
If a program is stopped by an M00, M01, selecting Cycle Start restarts the program at the following line of the G-code program.
To end a program, program: M02 or M30.
M02 leaves the next line to be executed as the M02 line. M30 rewinds the G-code file. These commands can have the following effects:

- Axis offsets are set to zero (like G92.2) and origin offsets are set to the default (like G54)
- Selected plane is set to XY (like G17)
- Distance mode is set to absolute (like G90)
- Feed rate mode is set to units per minute mode (like G94)
- Feed and speed overrides are set to on (like M48)
- Cutter Compensation is turned off (like G40)

- The spindle is stopped (like `M05`)
- 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 112).

9.4.3 Spindle Control (M03, M04, and M05)

To start the spindle turning clockwise at the currently programmed speed, program: `M03`

To start the spindle turning counterclockwise at the currently programmed speed, program: `M04`

The speed is programmed by the S word.

To stop the spindle from turning, program: `M05`

It's okay to use `M03` or `M04` if the spindle speed is set to 0; if this is done, the spindle won't start turning. If later the spindle speed is set above 0, the spindle starts turning. It is permitted to use `M03` or `M04` when the spindle is already turning, or to use `M05` when the spindle is already stopped.

9.4.4 Tool Change (M06)

To execute a tool change sequence, program: `M06`

`M06` behaves differently depending on whether or not the machine is equipped with an Automatic Tool Changer (ATC):

- If you have an ATC:
  - If the requested tool (T number) is assigned to the carousel, `M06` initiates an automatic tool change.

- If the tool is not assigned to the carousel, you're prompted to manually change the tool and select Cycle Start to confirm the tool change. This resumes the program.

- If you don't have an ATC:
  - `M06` commands the machine, stops the spindle, pauses program execution, and prompts operator to change tools by flashing Tool Change LED.
  - The program resumes after you select Cycle Start to confirm that the tool has been changed.

We recommend putting the `T~`, the `M06`, and the `G43 H~` on one line (block) of code.

EXAMPLE

```
N191 M06 T3 G43 H3
```

9.4.5 Coolant Control (M07, M08, and M09)

To turn coolant on, program: `M07`
To turn flood coolant on, program: `M08`
To turn all coolant off, program: `M09`
It's always okay to use any of these commands, regardless of what coolant is on or off.

9.4.6 Dust Shoe Control (M27 and M28)

To raise or retract the dust shoe, program: `M27`
To lower or extend the dust shoe, program: `M28`

9.4.7 Override Control (M48 and M49)

To enable the speed and feed override, program: `M48`
To disable both overrides, program: `M49`
It's okay to enable or disable the switches when they are already enabled or disabled.

9.4.8 Feed Override Control (M50)

To enable the feed rate override control, program: `M50 P1`
The P1 is optional.
To disable the feed rate control, program: `M50 P0`
When feed rate override control is disabled, the feed rate override slider has no influence, and all motion is executed at programmed feed rate (unless there is an adaptive feed rate override active).

9.4.9 Spindle Speed Override Control (M51)

To enable the spindle speed override control, program: `M51 P1`
The P1 is optional.
To disable the spindle speed override control, program: `M51 P0`
When spindle speed override control is disabled, the spindle speed override slider has no influence, and the spindle speed is equal to the value of the S word.

9.4.10 Set Current Tool Number (M61)

To change the current tool number while in MDI or manual mode, program: `M61 Q~`

- `Q~` is the tool number

Troubleshooting

It's an error if:

- `Q~` is not 0 or greater

9.4.11 Set Output State (M64 and M65)

> **Note:** These commands are only useful when the machine is equipped with the USB M-Code I/O Interface Kit.

There are four output relays available on the USB I/O module.
To activate output relays (contact close), program: `M64`
To deactivate output relays (contact open), program: `M65`
There are four contacts, numbered from 0 to 3. The contact is specified by the P word.

EXAMPLE

- Activating the first relay: `M64 P0`
- Activating the second relay: `M64 P1`

The outputs are deactivated using M65 with the P word specifying the relay.

EXAMPLE

- Deactivating the second relay: `M65 P1`
- Deactivating the fourth relay: `M65 P3`

There is only one P word and one relay per line. Each relay command must be done on an individual line.
The following is legal:

```
M64 P0
M64 P2
M64 P3
```

The following is not legal:

```
M64 P023
M64 P0 P2 P3
```

9.4.12 Wait on Input (M66)

> **Note:** This command is only useful when the machine is equipped with the USB M-Code I/O Interface Kit.

There are four digital inputs available on the USB I/O module.
`M66 P- | E- <L->`

- `P-` is the digital input number from 0 to 3.
- `L-` is the wait mode type:
  - Mode 0: IMMEDIATE – no waiting, returns immediately. The value of the input at that time is stored in parameter #5399.
  - Mode 1: RISE – waits for the selected input to perform a rise event.
  - Mode 2: FALL – waits for the selected input to perform a fall event.
  - Mode 3: HIGH – waits for the selected input to go to the HIGH state.
  - Mode 4: LOW – waits for the selected input to go to the LOW state.
- `Q-` is the timeout in seconds for waiting

The Q value is ignored if the L word is zero (IMMEDIATE). A Q value of zero is an error if the L word is non-zero.

9.5 PROGRAMMING INPUT CODES

Read the following sections for reference:

9.5.1 Feed Rate (F)

To set the feed rate, program: `F~`
Depending on the setting of the feed mode toggle, the rate may be in units-per-minute or units-per-rev of the spindle. The units are those defined by the G20/G21 mode. The feed rate may sometimes be overridden.

9.5.2 Spindle Speed (S)

To set the speed in revolutions per minute (rpm) of the spindle, program: `S~`

The spindle turns at the commanded speed when it has been programmed to start turning. It's okay to program an S word whether the spindle is turning or not. If the speed override switch is enabled and not set at 100 percent, the speed is different from what is programmed. It's okay to program S0, but the spindle does turn if that is done.

Troubleshooting

It's an error if:

- The S number is negative

9.5.3 Change Tool Number (T)

It's your responsibility to make sure that the machine is in a safe place for changing tools (for example, by using `G30`). This allows optimization of motion which can save time. You can provide a pause for manual intervention with `M00` or `M01` before the tool change.

Troubleshooting

It's an error if:

- A negative T number is used
- A T number larger than 1000 is used

9.6 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:

9.6.1 Parameters

Read the following sections for reference:

Parameters Reference

The RS274/NGC language supports parameters. Parameters are analogous to variables in other programming languages. PathPilot maintains an array of 10,320 numerical parameters. Many of them have specific uses. The parameters that are associated with fixtures are persistent over time. Other parameters are undefined when the operating system is loaded. The parameters are preserved when the interpreter is reset. Parameters 1 to 1000 can be used by the code of part-programs.

There are several types of parameters of different purpose and appearance. The only value type supported by parameters is floating-point; there are no string, Boolean or integer types in G-code like in other programming languages. However, logic expressions can be formulated with Boolean operators (AND, OR, XOR, and the comparison operators EQ, NE, GT, GE ,LT, LE), and the MOD, ROUND, FUP and FIX operators support integer arithmetic.

Parameter Syntax

There are three types of parameters, numbered, named local, and named global. The type of the parameter is defined by its syntax:

- Numbered - `#4711`
- Named local - `#<localvalue>`
- Named global - `#<_globalvalue>`

Parameter Scope

The scope of a parameter is either global or local within a subroutine. The scope of each parameter is inferred from its syntax. Subroutine parameters and named local parameters have local scope. Named global parameters and all numbered parameters starting from #31 are global in scope. RS274/NGC uses lexical scoping. In a subroutine, only the local parameters defined therein and any global parameters are visible. The local parameters of a calling procedure are not visible in a called procedure.

Behavior of Uninitialized Parameters

Uninitialized global parameters and unused subroutine parameters return the value zero when used in an expression. Uninitialized named parameters signal an error when used in an expression.

Parameter Mode

The mode of a parameter can either be read/write or read-only. Read/write parameters may be assigned values within an assignment statement. Read-only parameters cannot be assigned values. They may appear in expressions, but not on the left-hand side of an assignment statement.

Persistence and Volatility

Parameters can either be persistent or volatile. When the operating system is powered off, volatile parameters lose their values and are reset to zero. The values of persistent parameters are saved in a disc file and restored to their previous values when the operating system is powered on again. All parameters except numbered parameters in the current persistent range (5163 to 5390) are volatile.

Intended Use

Numbered parameters in the range #31-#5000, named global, and local parameters are available for general-purpose storage of floating-point values, like intermediate results, flags, etc., throughout program execution. They are read/write (can be assigned a value). Subroutine parameters, numbered parameters #1-#30, and system parameters are read-only and not available for general use. Subroutine parameters are used to hold the actual parameters passed to a subroutine. Numbered parameters in the range of #1-#30 are used to access offsets of coordinate systems. System parameters are used to determine the current running version and are read-only.

Numbered Parameters Reference

A numbered parameter is recognized by the pound symbol (#) followed by an integer between 1 and 5399. The parameter is referred to by this integer, and its value is whatever number is stored in the parameter. A value is stored in a parameter with the (=) operator.

Example: `#3 = 15` (set parameter 3 to 15)

A parameter setting does not take effect until after all parameter values on the same line have been found. For example, if parameter 3 has been previously set to 15 and the line: `#3=6 G01 X#3` is interpreted, a straight move to a point where X = 15 occurs before the value of parameter 3 is set to 6.

The # symbol takes precedence over other operations. For example, `#1+2` means the number found by adding 2 to the

value of parameter 1, not the value found in parameter 3. Of course, `#[1+2]` does mean the value found in parameter 3. The # character may be repeated; for example `##2` means the value of parameter whose index is the (integer) value of parameter 2. PathPilot maintains a number of read-only parameters. Only parameters for the relevant axes are maintained: (X Y Z A) for mill and (X Z) for lathe. The remaining parameters for unused axes are undefined.

Read-Only Parameters

- 1-30: Subroutine local parameters of call arguments. These parameters are local to the subroutine. For further information, see Programming with Subroutines later in this chapter
- 31-5000: G-code operator parameters. These parameters are global in G-code file
- 5061-5070: Result of G38.2 probe (X Y Z A B C U V W)
- 5161-5169: G28 home for (X Y Z A B C U V W)
- 5181-5189: G30 home for (X Y Z A B C U V W)
- 5210: 1 if G92 offsets are active, 0 if not
- 5211-5219: G92 offset (X Y Z A B C U V W)
- 5220: Current coordinate system number 1-9 for G54 - G59.3
- 5221-5230: Coordinate System 1, G54 (X Y Z A B C U V W R) – R denotes XY rotation angle around Z-axis
- 5241-5250: Coordinate System 2, G55 (X Y Z A B C U V W R)
- 5261-5270: Coordinate System 3, G56 (X Y Z A B C U V W R)
- 5281-5290: Coordinate System 4, G57 (X Y Z A B C U V W R)
- 5301-5310: Coordinate System 5, G58 (X Y Z A B C U V W R)
- 5321-5330: Coordinate System 6, G59 (X Y Z A B C U V W R)
- 5341-5350: Coordinate System 7, G59.1 (X Y Z A B C U V W R)
- 5361-5370: Coordinate System 8, G59.2 (X Y Z A B C U V W R)
- 5381-5390: Coordinate System 9, G59.3 (X Y Z A B C U V W R)
- 5399: Result of M66 – check or wait for input
- 5400: Current tool number
- 5401-5409: Tool offset (X Y Z A B C U V W)
- 5410: Current tool diameter
- 5411: Current tool front angle
- 5412: Current tool back angle
- 5420-5428: Current position including offsets in current program units (X Y Z A B C U V W)

Subroutine Parameters Reference

Subroutine parameters are specifically reserved for call arguments. By definition, these are parameters #1-#30 and are local to the subroutine.

Named Parameters Reference

Named parameters work like numbered parameters, but are easier to read and remember. All parameter names are converted to lowercase and have spaces and tabs removed. Named parameters must be enclosed with `< >` marks. `#<named parameter here>` is a local named parameter. By default, a named parameter is local to the scope in which it is assigned.

You can't access a local parameter outside of its subroutine. This is so two subroutines can use the same parameter names without fear of one subroutine overwriting the values in another.

`#<_global named parameter here>` (i.e., name starting with an underscore) is a global named parameter. They are accessible from within called subroutines and may set values within subroutines that are accessible to the caller. As far as scope is concerned, they act just like regular numeric parameters. They are not made persistent by storage in a file. The global parameters `_a`, `_b`, `_c`, . . . `_z` are reserved for special use. Do not use these parameters.

EXAMPLES

- `#<_endmill_dia> = 0.049` is a declaration of named global variable.
- `#<_endmill_rad> = [#<_endmill_dia>/2.0]` is a reference to previously declared global variable.
- `o100 call [0.0] [0.0] [#<_inside_cutout>-#<_endmill_dia>] [#<_Zcut>] [#<_feedrate>]` is mixed literal and named parameters.

9.6.2 Expressions

An expression is a set of characters starting with a left bracket ([) and ending with a right bracket (]). Located between the brackets are numbers, parameter values, binary operators, functions, and other expressions. An expression is evaluated to produce a number. An example of an expression is:
`[1 + acos[0] - [#3 ** [4.0/2]]]`
All expressions on a line are evaluated when the line is read and before anything on the line is executed.
Read the following sections for reference:

Binary Operators Reference

Binary operators only appear inside expressions. There are three types of binary operators: mathematical, logical, and relational.
There are four basic mathematical operations: addition (+), subtraction (-), multiplication (*), and division (/). In addition, the modulus operation (MOD) finds the remainder after division of one number by another number. The power operation (**) of raising the number on the left of the operation to the power on the right. There are three logical operations: non-exclusive or (OR), exclusive or (XOR), and logical and (AND).
The relational operators are equality (EQ), inequality (NE), strictly greater than (GT), greater than or equal to (GE), strictly less than (LT), and less than or equal to (LE).
Binary operators are divided into several groups according to their precedence as follows, from highest to lowest:

1. **
2. * / MOD
3. + -
4. EQ NE GT GE LT LE
5. AND OR XOR

If operations in different precedence groups are strung together, operations with a higher precedence are performed before operations with a lower precedence. If an expression contains more than one operation with the same precedence, the operation on the left is performed first.

EXAMPLE
`[2.0 / 3 * 1.5 - 5.5 / 11.0]` is equivalent to
`[[[2.0 / 3] * 1.5] - [5.5 / 11.0]]`
which is equivalent to `[1.0 - 0.5]`
which is
`0.5`

The logical operations and modulus are to be performed on any real numbers, not just on integers. The number zero is equivalent to logical false, and any non-zero number is equivalent to logical true.

Functions Reference

The available functions are:

- `ATAN[Y]/[X]`: Four quadrant inverse tangent
- `ABS[arg]`: Absolute value
- `ACOS[arg]`: Inverse cosine
- `ASIN[arg]`: Inverse sine
- `COS[arg]`: Cosine
- `EXP[arg]`: e raised to the given power (ex)
- `FIX[arg]`: Round down to integer
- `FUP[arg]`: Round up to integer
- `ROUND[arg]`: Round to nearest integer
- `LN[arg]`: Base-e logarithm
- `SIN[arg]`: Sine
- `SQRT[arg]`: Square root
- `TAN[arg]`: Tangent
- `EXISTS[arg]`: Check named parameter

9.6.3 Subroutines

Subroutines are subprograms that are called from inside another program.
Read the following sections for reference:

Subroutines Reference

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

MACHINE MAINTENANCE

IN THIS SECTION, YOU'LL LEARN:

- About the required maintenance procedures that you must do so that this machine operates as designed.

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

CONTENTS

10: MACHINE MAINTENANCE

10.1 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.

10.2 MAINTENANCE SCHEDULES

To keep your machine running as smoothly as possible, you must regularly do the following maintenance procedures.

Note: Before you begin any maintenance procedures, read and understand Maintenance Safety.

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 209). For any additional support, we can help. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

10.2.1 Daily

- ☐ Clean the machine of any dust or swarf buildup with a vacuum and brushes.
- ☐ Wipe dust off of the linear rails and ball screws with a clean cloth.
- ☐ Examine cutting tools for chips or dull cutting edges.
- ☐ Inspect the spindle taper, collet nut, and collets for buildup and, if necessary, clean the components.
- ☐ Use a rust inhibitor on all exposed, non-lubricated, non-painted metal surfaces.

  Note: Don't use rust inhibitor on the ball screws or the linear rails.

10.2.2 Weekly

- ☐ Clean all exterior surfaces with a clean rag.
- ☐ Inspect the dust collection hose and dust collector for blockages (or any large debris that could cause a blockage).
- ☐ Examine the chiller's water level and, if necessary, add distilled water.
- ☐ Verify that the machine's lubrication points have been properly lubricated.

10.2.3 Monthly

- ☐ Clean the electrical cabinet vents of dust with a clean cloth or compressed air.
- ☐ Inspect the spindle's ER20 taper for wear, damage, or dust buildup.

10.2.4 Quarterly

- ☐ Drain the water from the chiller and replace it with fresh, distilled water.
- ☐ Examine the water chiller lines for flexibility and signs of wear (like cracking). Replace the lines if stiffness has increased or if they're damaged.
- ☐ Lubricate the ball screws.

10.2.5 Semi-Annually

- ☐ Lubricate the linear blocks.
- ☐ Lubricate the axis motor couplers with synthetic silicone grease.

10.3 REGULARLY MAINTAINING THE MACHINE

10.3.1 Clean the Linear Rails and Ball Screws

You must clean the linear rails and ball screws for the machine to operate properly and to extend its service life. Doing so helps to reduce the wear in the seals and increase the service life of the parts.

To clean the linear rails and ball screws:

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. Wipe the linear rails (daily, or every 8 hours of operation) with a clean, non-linting towel or cloth.
3. Wipe the ball screws on the X and Z axes (daily, or every 8 hours of operation) with a clean, non-linting towel or cloth.
4. Inspect the Y-axis ball screw with a flashlight, and determine if it must be cleaned of dust and debris. If necessary, wipe the ball screw with a clean, non-linting towel or cloth.

> **Note:** The Y-axis ball screw is protected from dust and debris by the router table. This means that you can clean it less frequently.

5. 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.
6. Jog the machine through its full length of travel.
   As the machine moves, the bearing blocks apply a thin layer of grease to the linear rail, and the ball nuts apply a thin layer of grease to the ball screws.

10.3.2 Clean the Spindle Taper, Collet Nut, and Collet

While you use the machine, dust and resin can build up in the spindle taper, collet nut and the slots of the collets. Before each tool change, you must inspect and clean the spindle taper, collet nut, and collets (and, if necessary, replace the components).

> **WARNING!** Tool Pullout Hazard: You must verify that the spindle taper, collet nut, and collet aren't worn and don't have dust buildup. If you don't, tool life and performance could decrease, and it could introduce the possibility for tool runout and reduced holding power on the tool.

Spindle Taper

- Inspect and clean the spindle taper as necessary.

Collet Nut

- Inspect the inside of the collet nut for dust and resin buildup before each tool change, and clean it if necessary.

Figure 10-1: Example of a collet nut with dust and resin buildup.

- Inspect the collet nut for wear and damage every day, and replace it if necessary.

Collet

- Inspect the slots of the collet for dust and resin buildup, and clean it if necessary.

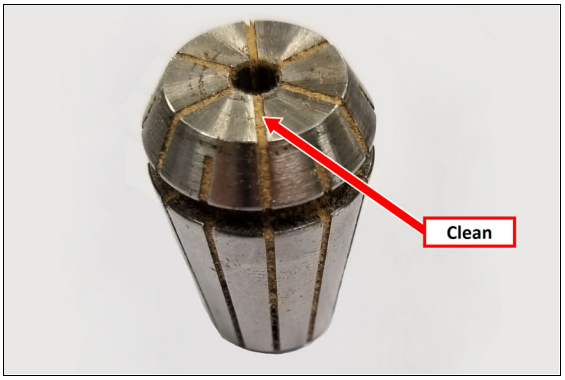


Figure 10-2: Example of a collet with dust and resin buildup.

- Inspect the collet for wear and damage before each tool change, and replace it if necessary.

10.3.3 Maintain the Chiller

The chiller circulates a continuous supply of cool water through the spindle, which regulates its temperature.

> ***NOTICE!*** To keep the spindle's temperature regulated, you must verify that the chiller is always operating properly by maintaining it as detailed in this section. If you don't, there's a risk that the spindle could overheat, which could cause spindle bearing failure.

- Only use distilled water in the chiller to avoid corrosion and/or bacterial buildup in the chiller, coolant lines, and spindle.
- Examine the water level of the chiller weekly and, if necessary, refill it with distilled water.
- Drain and replace the water in the chiller with fresh, distilled water every 3 months. Over time, buildup of corrosion and dirt in the chiller can reduce the performance of the chiller.

10.3.4 Lubricate the Machine

To keep the machine operating properly, and to extend the service life of the machine, you must verify that the linear rails and ball screws are properly lubricated.

Linear Rails

The linear bearing blocks are sealed and lubricated during machine assembly, which makes them relatively low maintenance components. The recommended service interval (from the linear bearing manufacturer) is between 500-1000 km, depending on load rating. We recommend lubricating the linear bearing blocks every 6 months, which assumes that you're using the machine at its maximum velocity for 8 hours every day, and that the lubrication interval is every 500 km.

- **Recommended Lubrication Quantity** 0.3 cm^3 grease per block

> ***NOTICE!*** You must only use the amount of lubrication and at the pressure specified in this section. If you use excessively high quantities of lubricant, or excessively high lubricating pressure, it could cause machine damage.

- **Maximum Lubricating Pressure** 30 bar
- **Recommended Grease Type** Hiwin G05 General Type Grease (or greases that are in accordance with DIN 51825 of consistency class NLGI No. 2 as specified by DIN 51818)

> **Note:** Don't use greases with solid particles, like graphite or MoS2.

To lubricate the linear rails:

1. Identify the machine's bearing blocks.

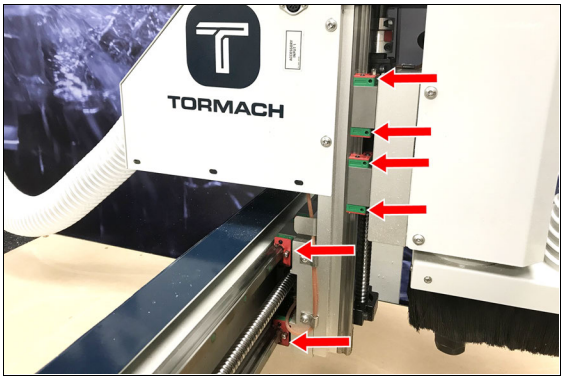


Figure 10-3: Example of bearing blocks.

2. Identify the lubrication port on the bearing blocks.

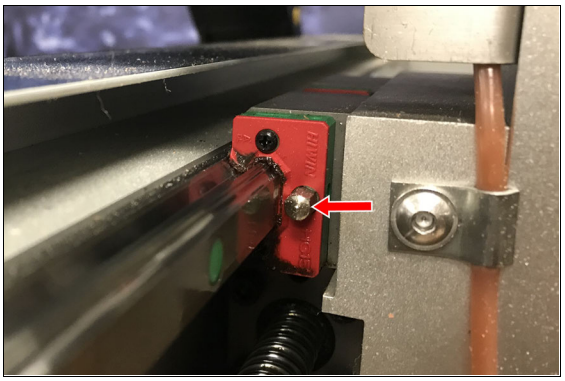


Figure 10-4: Lubrication port on a bearing block.

3. Find the Grease Gun (PN 50360) and the Grease Nozzle Kit (PN 50389) provided with the machine. From the Grease Nozzle Kit, identify the concave nozzle.

4. Assemble the Grease Gun with the concave nozzle, and lubricate the linear bearings with the recommended lubrication quantity once every 6 months.

Figure 10-5: Lubricating a bearing block with the Grease Gun.

Ball Screws

The recommended lubrication interval (from the ball screw manufacturer) is every 2-3 months or 100 km of travel. We recommend lubricating the ball screws every 2-3 months, which assumes that you're using the machine at its maximum velocity for 8 hours every day.

- **Maximum Lubricating Pressure** 30 bar

> ***NOTICE!*** You must only use the amount of lubrication and at the pressure specified in this section. If you use excessively high quantities of lubricant, or excessively high lubricating pressure, it could cause machine damage.

- **Recommended Grease Type** Hiwin G05 General Type Grease (or greases that are in accordance with DIN 51825 of consistency class NLGI No. 2 as specified by DIN 51818)

> **Note:** Don't use greases with solid particles, like graphite or MoS2.

1. Identify the three remote-mounted lubrication ports.
2. Use the Grease Gun (PN 50360) provided with the machine (and its attachments) to lubricate the ball screws with the recommended lubrication quantity once every 2-3 months.

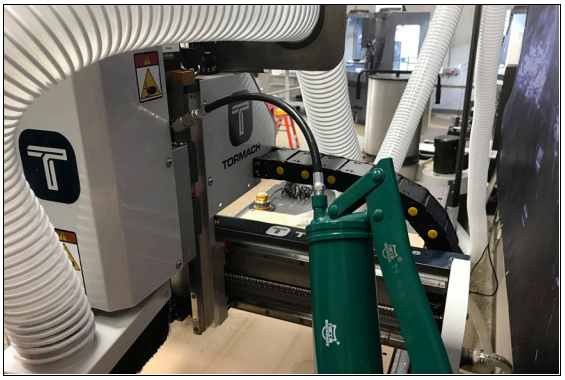


Figure 10-6: Lubricating a remote-mounted lubrication port with the Grease Gun.

10.3.5 Lubricate the Axis Motor Couplers

The rubber bushing in the axis motor couplers may begin to squeak or make a ticking noise after time. A small amount of synthetic silicone grease on the mating surfaces of the red polyurethane bushing can prevent them from squeaking.
To lubricate the axis motor couplers:

1. Remove the axis motor.
2. Separate the two halves of the coupler, and put a small amount of synthetic silicone grease on the rubber bushing faces.
3. Re-assemble the coupler, and re-install the motor.

10.3.6 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 all exterior surfaces with a mild cleaner.
- 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.

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.

CONTENTS

11: TROUBLESHOOTING

11.1 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.

11.2 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 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.

11.3 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

11.4 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-, Y- and Z-axes have one limit switch each. The X-axis limit switch is located on the left side of the gantry (X- direction). The Y-axis limit switch is located on the left side of the machine at the Y- end of travel. The Z-axis limit switch is located at the upper limit of motion.

  To learn more about the limit switches, see "Axes Drive Subsystem" (page 192).

11.5 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.
- **24 Vdc Power Supply** Indicates power to the supply.
- **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 Power** When on, indicates power to the control board.
- **Control Board PC** When flashing, 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.

11.6 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 and the PathPilot controller.

To troubleshoot the power distribution subsystem, read the following:

11.6.1 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.

11.7 CONTROL POWER SUBSYSTEM

To troubleshoot the control power subsystem, read the following:

11.7.1 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 402.	Before you replace the DC power supply, power off the machine (see "Power Off the Machine" (page 54)).

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 104. 2. Measure for 115 Vac nominal between wires 111 and 108.	Before you reset the tripped breaker, power off the machine (see "Power Off the Machine" (page 54)).

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 121. • 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.

11.8 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:

11.8.1 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 54)). 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 J6 ribbon cable from the control board to the axes.

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" (on the next page).

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.

11.8.2 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 54)). 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 53)) 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 54)). 2. 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. 3. Power on the machine (see "Power On the Machine" (page 53)). 4. 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. 5. 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 54)). 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 54)). 2. Measure the resistance of windings at the green connector on the axis driver (see "Motor Resistance Reference" (below)). 3. 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: 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)	

X-, Y-, Z-Axis		Resistance
213	214, 215	0.5-2.0 Ω
216	217, 218	0.5-2.0 Ω
229	230, 231	0.5-2.0 Ω
214	215	0.5-2.0 Ω
217	218	0.5-2.0 Ω
230	231	0.5-2.0 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	204, 203	55-75 Vdc
F2 Y	Y-axis	206, 205	55-75 Vdc
F3 Z	Z-axis	208, 207	55-75 Vdc
F4 A	A-axis	210, 209	55-75 Vdc

11.8.3 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 54)). 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 193).	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 54)). 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 53)). 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 54)). 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 53)). Then, carefully measure DC voltage on wires 211 (common) and 212 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.

11.8.4 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 123) and "About Reset Mode" (page 123).

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 54)). 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 455 to 485 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.
The **Y Limit** light is always on, even though the switch is not actuated.	Jumper wires 457 to 485 on the machine control board.	
The **Z Limit** light is always on, even though the limit switch is not actuated.	Jumper wires 459 to 485 on the machine control board.	
The **X Limit** light is never on, even though the switch is actuated.	Remove wire 455 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 54)). Then, disconnect the limit switch connectors located near the switch on the gantry. 2. Power on the machine (see "Power On the Machine" (page 53)). 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 457 on the machine control board.	
The **Z Limit** light is never on, even though the limit switch is actuated.	Remove wire 459 on the machine control board.	

11.8.5 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. • Verify that the collet nut is properly tightened on the spindle before you start cutting. • Verify that the spindle taper, collet nut, and collet are properly cleaned.	For information, see "Clean the Spindle Taper, Collet Nut, and Collet" (page 183).

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: 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 188).

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.

11.9 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 machine is reset.
3. The spindle brake resistor thermal switch isn't tripped.

To troubleshoot the spindle drive subsystem, read the following:

11.9.1 The Spindle Won't Turn

Cause: There's a water chiller error.		
Probability	**How-To Steps**	**Need More?**
High	1. If the water chiller isn't already on, turn it on. 2. Examine both ends of the water chiller cable to verify that they're connected (to both the back of the water chiller and to the Chiller Alarm Port on the machine stand). 3. Examine the water level in the water chiller. For information, see "Maintain the Chiller" (page 184).	To prevent overheating and damage, PathPilot doesn't allow the spindle to run if: • The chiller is disconnected from the machine. • There's a water chiller error.
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 114 and 120 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 54)). 2. Examine the circuit for loose wires. 3. Power on the machine (see "Power On the Machine" (page 53)) and test operation.

Probability	How-To Steps
Low	Thermal switch (TS1) tripped, preventing K2 from latching. 1. Power off the machine (see "Power Off the Machine" (page 54)). 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 420 and 422 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 421 to wire 422. Make a jumper wire and, carefully, momentarily jumper wires 422 and 420. ◦ 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 422 to 420 via a relay to create the start pulse. Measure wire 422 for 24 Vdc power. If present, the control board or wire 420 connected to J10.3 is defective. Power off the machine (see "Power Off the Machine" (page 54)), and jumper J10.1 to J10.3 Power on the machine (see "Power On the Machine" (page 53)) and check the VFD for a display. If the VFD reads **rdy**, the control board is defective. If not, wire 420 may be broken. Lift the connections of wire 420 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 203).	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 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 120 and 114 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 54)). 2. Wait 30 seconds, and then remove wires 123, 124, and 125 from the VFD terminals. 3. Measure the resistance between: • Wires 123 and 124 • Wires 123 and 125 • Wires 124 and 125 Resistance should be in the range of approximately 1-2 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)	447	448	14-20 Vdc	0 Vdc
Reverse	447	450	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.

11.10 OPERATOR CONSOLE TROUBLESHOOTING

11.10.1 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.

11.10.2 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.	

11.10.3 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.

11.10.4 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).

11.10.5 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).

DIAGRAMS AND PARTS LISTS

IN THIS SECTION, YOU'LL LEARN:

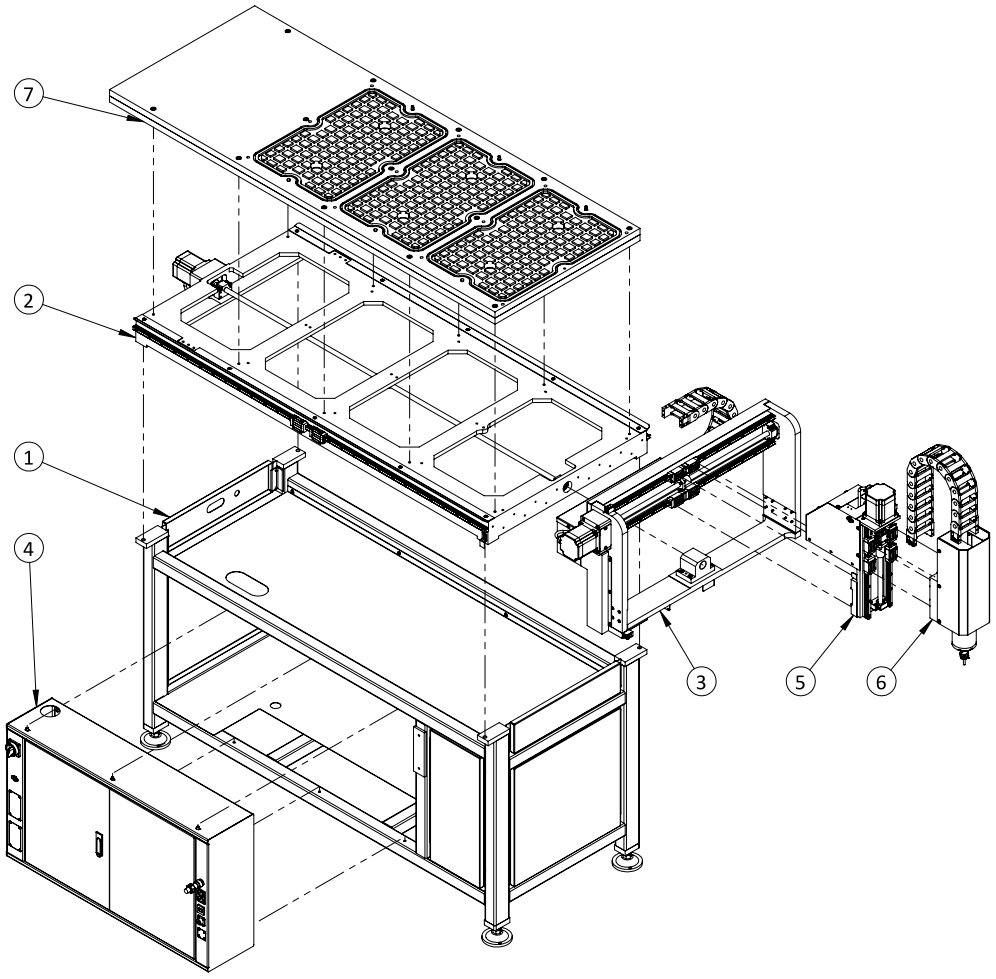
- About this machine's components.

> ***NOTICE!*** Only use Tormach-approved parts when making replacements. If you don't replace parts with those listed in this section, you may void your warranty.

CONTENTS

12: DIAGRAMS AND PARTS LISTS

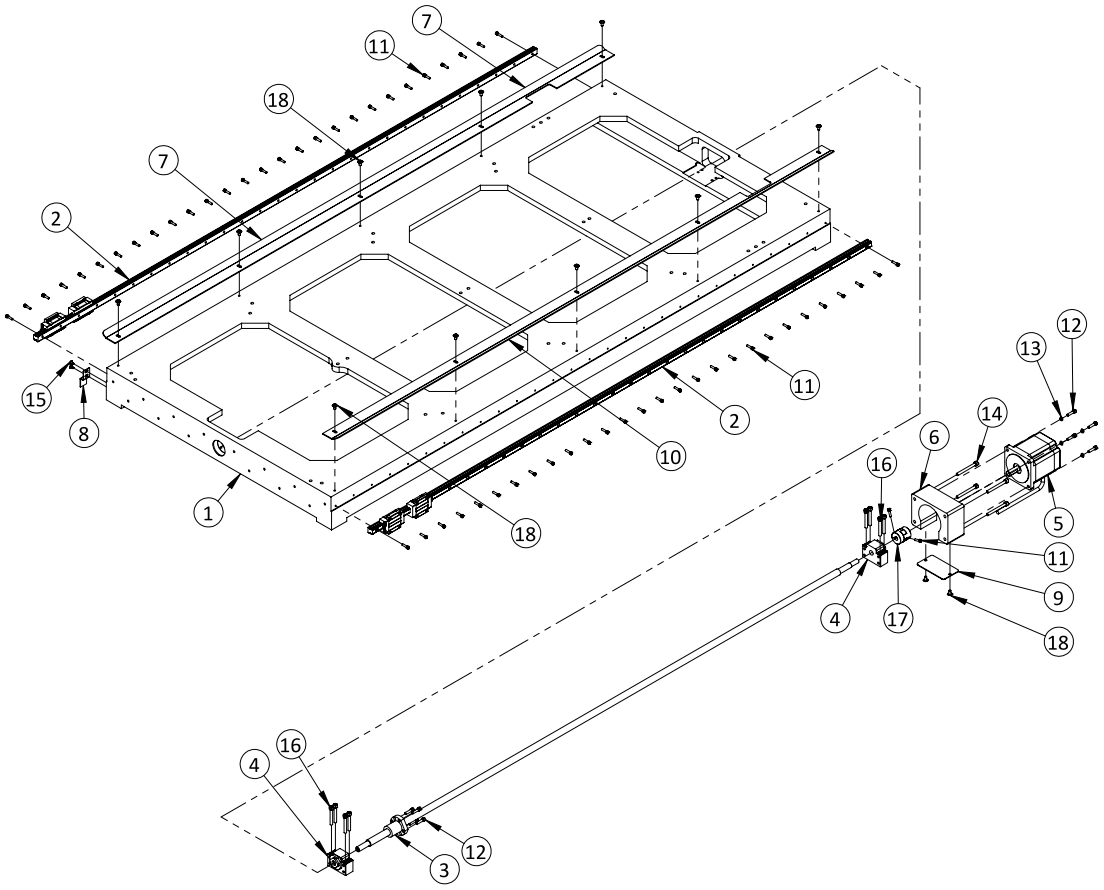
12.1 MACHINE EXPLODED VIEW



12.2 MACHINE PARTS LIST

ID	Description	Quantity
1	Stand Assembly (PN 38312)	1
2	Base Casting Assembly (PN 38319)	1
3	Gantry Assembly (PN 39299)	1
4	Electrical Cabinet Assembly (PN 38835)	1
5	X-Axis Carriage Assembly (PN 39304)	1
6	Z-Axis Spindle Head Assembly (PN 38367)	1
7	Spoilboard Assembly (PN 39363)	1

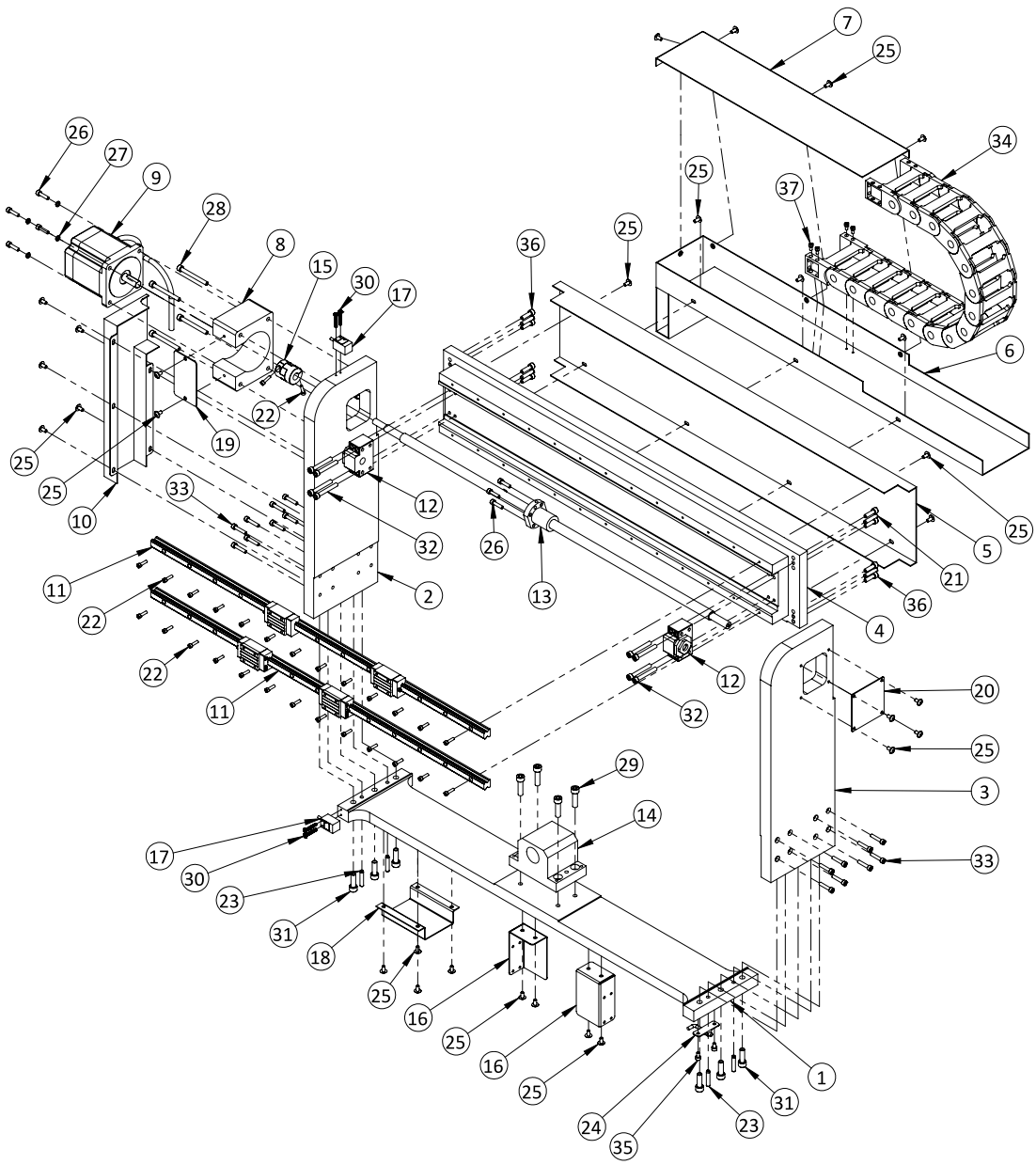
12.3 BASE EXPLODED VIEW



12.4 BASE PARTS LIST

ID	Description	Quantity
1	Base Casting (PN 38320)	1
2	Linear Guideway Assembly, Y-Axis (PN 39049)	2
	Linear Rail, Y-Axis, 15 mm × 1650 mm (PN 38322)	1
	Y-Axis Linear Guide Block (PN 39048)	2
	Linear Rail Bolt Cap (PN 39615)	28
3	Y-Axis Ball Screw Assembly (PN 38323)	1
	Ball Screw, Rolled, 16 mm × 5 mm - 1650 mm (PN 38324)	1
	Y-Axis Ball Nut (Nut Only) (PN 38325)	1
4	Ball Screw Support Bearing, Fixed (PN 38328)	2
5	Motor, Stepper, NEMA 34, 1.2 deg, 450 Ncm, 3-phase, 400 mm Cable (PN 50374)	1
6	Motor Mount, NEMA 34 (PN 39063)	1
7	Y-Axis Linear Rail Cover, Left (PN 39050)	1
8	Y Limit Switch Flag (PN 39073)	1
9	Cover, XY Axis Motor Mount (PN 39410)	1
10	Y-Axis Linear Rail Cover, Right (PN 39566)	1
11	Screw, Socket Head Cap, M4 × 0.7 - 16 (PN 37751)	58
12	Screw, Socket Head Cap, M5 × 0.8 - 20 (PN 30357)	8
13	Washer, Split Lock, M5 (PN 31572)	4
14	Screw, Socket Head Cap, M6 × 1 - 60 (PN 30356)	4
15	Screw, Button Head Cap, Flanged M4 × 0.7 - 8 (PN 50484)	2
16	Screw, Socket Head Cap, M6 × 1 - 45 (PN 31332)	8
17	Shaft Coupling, Jaw, One Piece Split, 10 mm × 0.5 in. - 35 mm (PN 39318)	1
18	Screw, Button Head Cap (Flanged), M5 × 0.8 - 10, Stainless Steel (PN 38205)	12

12.5 GANTRY EXPLODED VIEW

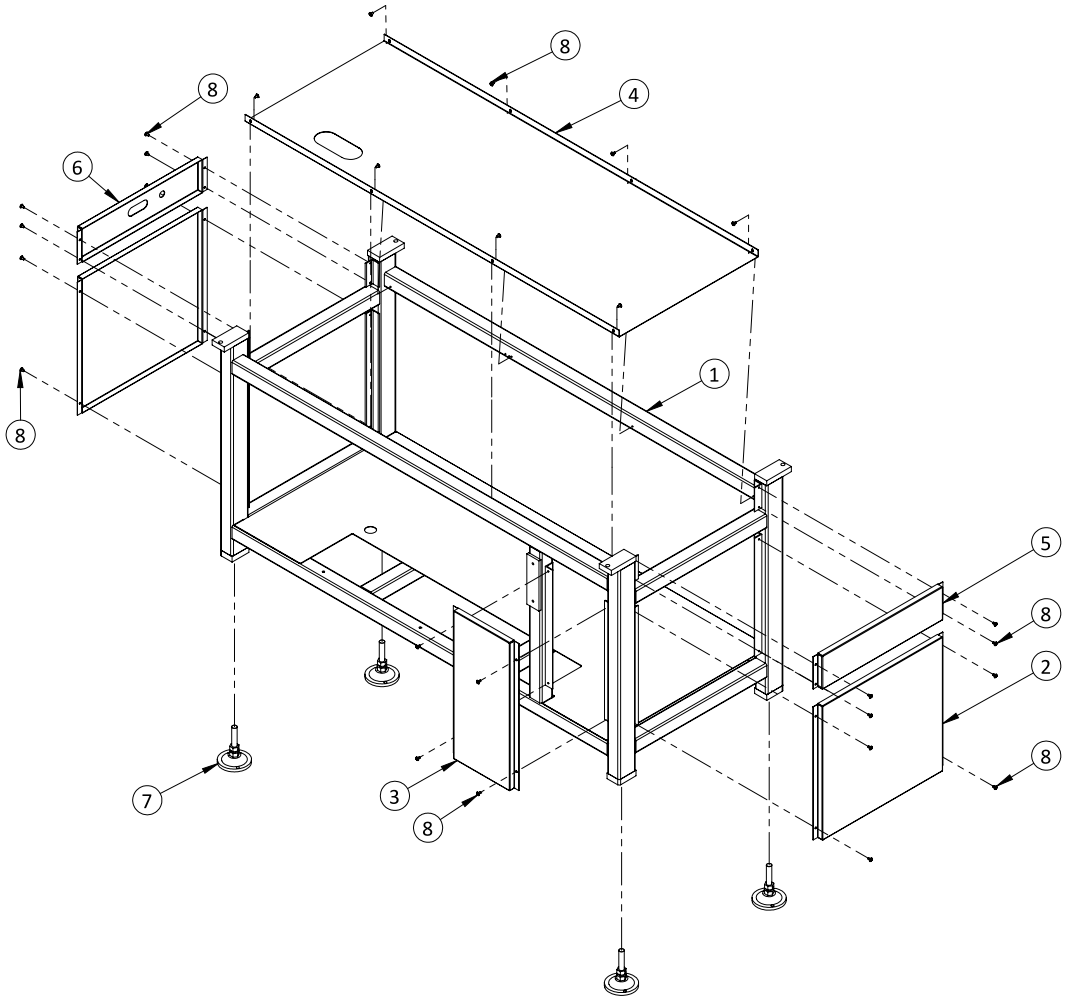


12.6 GANTRY PARTS LIST

ID	Description	Quantity
1	Lower Gantry Cross Beam (PN 39059)	1
2	Bridge Support, Left Side (PN 39057)	1
3	Bridge Support, Right Side (PN 39058)	1
4	X-Axis Bridge (PN 39055)	1
5	Rear Cover, X-Axis Bridge (PN 39056)	1
6	X-Axis Wire Tray (PN 39060)	1
7	X-Axis Wire Track Cover (PN 39062)	1
8	Motor Mount, NEMA 34 (PN 39063)	1
9	Motor, Stepper, NEMA 34, 1.2 deg, 450 Ncm, 3-phase, 400 mm Cable (PN 50374)	1
10	Cover, Gantry Left Side (PN 39141)	1
11	Linear Guideway Assembly, X-Axis (PN 39066)	2
	Linear Rail, X-Axis 15 mm × 800 mm (PN 39065)	1
	X/Z-Axis Linear Guide Block (PN 39301)	2
	Linear Rail Bolt Cap (PN 39615)	13
12	Ball Screw Support Bearing, Fixed (PN 38328)	2
13	X-Axis Ball Screw Assembly (PN 39302)	1
	Ball Screw, Rolled, 15 mm × 5 mm - 853 mm (PN 39064)	1
	X-Axis Ball Nut (Nut Only) (PN 39303)	1
14	Ball Nut Carrier, Y-Axis (PN 39054)	1
15	Shaft Coupling, Jaw, One Piece Split, 10 mm × 0.5 in. - 35 mm (PN 39318)	1
16	Y-Axis Drag Chain Bracket (PN 39409)	2
17	Limit Switch, Rectangular Proximity Sensor (PN 39074)	2
18	Y-Axis Cable Tray (PN 39408)	1
19	Cover, XY Axis Motor Mount (PN 39410)	1
20	Access Cover, X-Axis Ball Screw Mount (PN 39069)	1
21	Pin, 6 mm × 28 mm, Steel, Pull-Out, M4 (PN 39419)	4
22	Screw, Socket Head Cap, M4 × 0.7 - 16 (PN 37751)	28
23	Pin, 6 mm × 30 mm, Steel, Pull-Out, M4 (PN 39538)	4
24	Remote Oil Line Fitting (PN 39539)	1
25	Screw, Button Head Cap (Flanged), M5 × 0.8 - 10, Stainless Steel (PN 38205)	29
26	Screw, Socket Head Cap, M5 × 0.8 - 20 (PN 30357)	9

ID	Description	Quantity
27	Washer, Split Lock, M5 (PN 31572)	4
28	Screw, Socket Head Cap, M6 × 1 - 60 (PN 30356)	4
29	Screw, Socket Head Cap, M8 × 1.25 - 30 (PN 30544)	4
30	Screw, Pan Head Machine, M4 × 0.7 - 25, Stainless Steel (PN 50391)	4
31	Screw, Socket Head Cap, M8 × 1.25 - 25 (PN 31618)	6
32	Screw, Socket Head Cap, M6 × 1 - 45 (PN 31332)	8
33	Screw, Socket Head Cap, M5 × 0.8 - 25 (PN 30530)	16
34	Drag Chain, X-Axis (PN 39061)	1
35	Screw, Socket Head Cap, M5 × 0.8 - 8 (PN 30844)	2
36	Screw, Socket Head Cap, M6 × 1 - 20 (PN 30832)	8
37	Screw, Socket Head Cap, M4 × 0.7 - 8 (PN 30891)	4

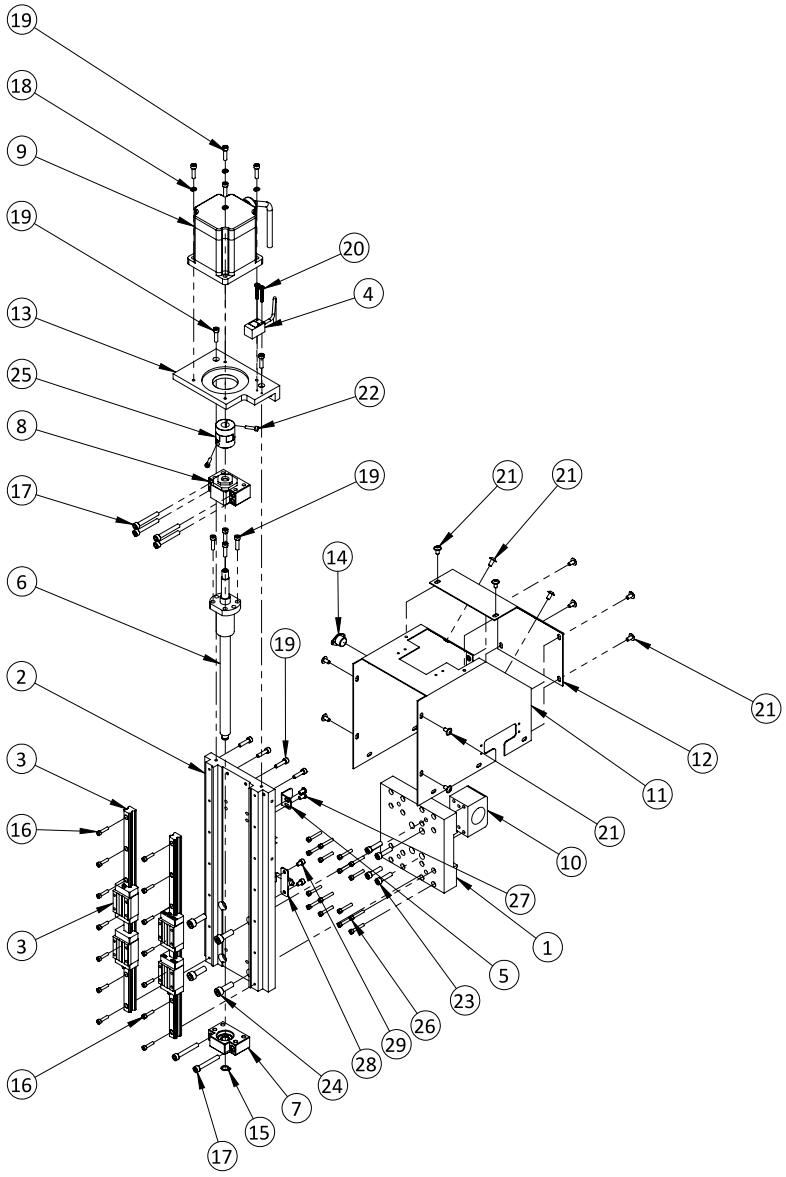
12.7 STAND EXPLODED VIEW



12.8 STAND PARTS LIST

ID	Description	Quantity
1	24R Stand (PN 38314)	1
2	Front End Panel (PN 38316)	2
3	Side Panel (PN 39406)	1
4	Drag Chain Undertray (PN 39544)	1
5	Upper Front End Panel (PN 39542)	1
6	Upper Back End Panel (PN 39543)	1
7	Machine Foot, M16 × 2 Thread (PN 38313)	4
8	Screw, Button Head Cap (Flanged), M5 × 0.8 - 10, Stainless Steel (PN 38205)	28

12.9 X-AXIS CARRIAGE EXPLODED VIEW

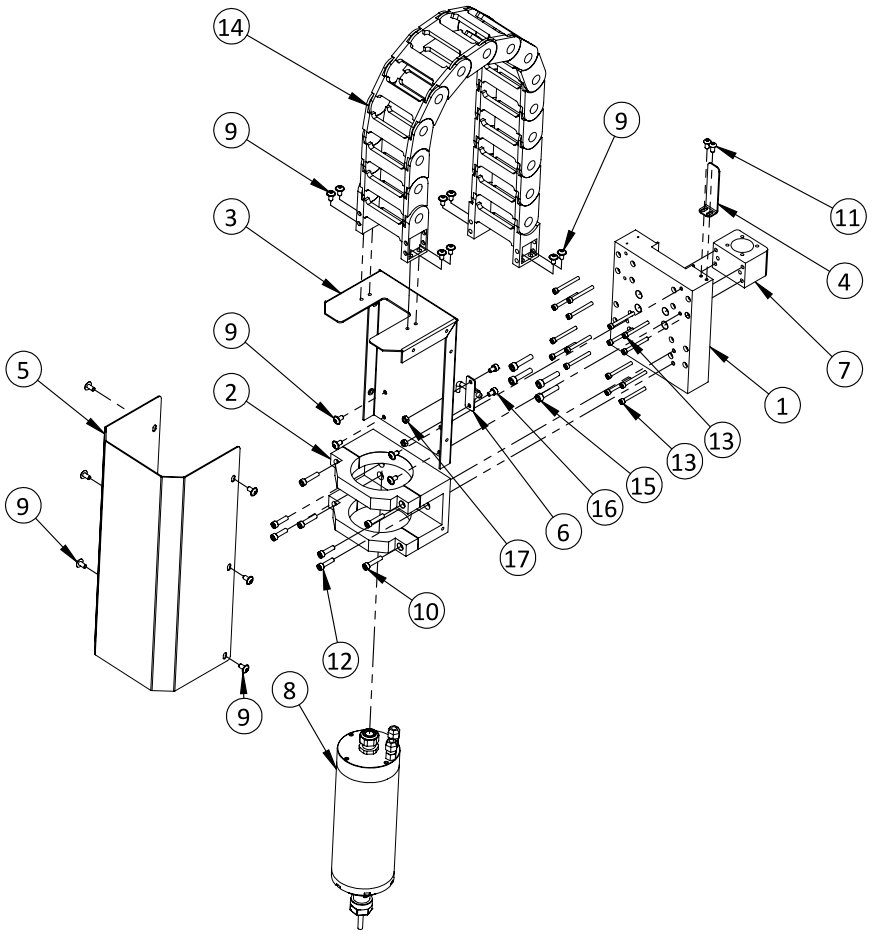


12.10 X-AXIS CARRIAGE PARTS LIST

ID	Description	Quantity
1	X Carriage Casting (PN 39075)	1
2	Z-Axis Linear Rail Plate (PN 38368)	1
3	Linear Guideway Assembly, Z-Axis (PN 39067)	2
	Linear Rail, Z-Axis, 15 mm × 370 mm (PN 38375)	1
	X/Z-Axis Linear Guide Block (PN 39301)	2
	Linear Rail Bolt Cap (PN 39615)	7
4	Limit Switch, Rectangular Proximity Sensor (PN 39074)	1
5	X Limit Switch Flag (PN 39078)	1
6	Z-Axis Ball Screw Assembly (PN 38372)	1
	Ball Screw, Rolled, 16 mm × 5 mm - 321 mm (PN 38373)	1
	X-Axis Ball Nut (Nut Only) (PN 38374)	1
7	Ball Screw Support Bearing, Floating (PN 39079)	1
8	Ball Screw Support Bearing, Fixed (PN 38328)	1
9	Motor, Stepper, NEMA 34, 1.2 deg, 450 Ncm, 3-phase, 400 mm Cable (PN 39587)	1
10	X-Axis Ball Nut Carrier (PN 39076)	1
11	Cover, Z-Axis Rear (PN 39084)	1
12	Access Panel, Z-Axis Rear (PN 39142)	1
13	Z-Axis Motor Mounting Plate (PN 38371)	1
14	DIN5 Connector Assembly (PN 30178)	1
15	Retaining Ring, External, 10 mm (PN 39540)	1
16	Screw, Socket Head Cap, M4 × 0.7 - 18 (PN 38734)	14
17	Screw, Socket Head Cap, M6 × 1 - 45 (PN 31332)	6
18	Washer, Split Lock, M5 (PN 31572)	4
19	Screw, Socket Head Cap, M5 × 0.8 - 20 (PN 30357)	14
20	Screw, Pan Head Machine, M4 × 0.7 - 25, Stainless Steel (PN 50391)	2
21	Screw, Button Head Cap (Flanged), M5 × 0.8 - 10, Stainless Steel (PN 38205)	15
22	Screw, Socket Head Cap, M4 × 0.7 - 16 (PN 37751)	2
23	Screw, Socket Head Cap, M6 × 1 - 25 (PN 31685)	4
24	Screw, Socket Head Cap, M8 × 1.25 - 25 (PN 31618)	4
25	Shaft Coupling, Jaw, One Piece Split, 10 mm × 0.5 in. - 35 mm (PN 39318)	1

ID	Description	Quantity
26	Screw, Socket Head Cap, M4 × 0.7 - 25 (PN 50486)	16
27	Screw, Button Head Cap, M5 × 0.8 - 10 (PN 35774)	2
28	Remote Oil Line Fitting (PN 39539)	1
29	Screw, Socket Head Cap, M5 × 0.8 - 8 (PN 30844)	2

12.11 Z-AXIS SPINDLE HEAD EXPLODED VIEW



12.12 Z-AXIS SPINDLE HEAD PARTS LIST

ID	Description	Quantity
1	Z Carriage Block (PN 38369)	1
2	Spindle Motor Mount, 80 mm (PN 39077)	1
3	Rear Spindle Cover (PN 39085)	1
4	Z Limit Switch Flag (PN 39082)	1
5	Front Spindle Cover (PN 39086)	1
6	Remote Oil Line Fitting (PN 39539)	1
7	X-Axis Ball Nut Carrier (PN 39076)	1
8	Spindle, 80 mm, 1.5 kW, ER20, 400 Hz, 24,000 rpm (PN 39259)	1
9	Screw, Button Head Cap (Flanged), M5 × 0.8 - 10, Stainless Steel (PN 38205)	18
10	Screw, Socket Head Cap, M5 × 0.8 - 25 (PN 30530)	4
11	Screw, Button Head Cap, M5 × 0.8 - 10 (PN 35774)	2
12	Screw, Socket Head Cap, M5 × 0.8 - 20 (PN 30357)	4
13	Screw, Socket Head Cap, M4 × 0.7 - 40 (PN 50485)	16
14	Drag Chain, Z-Axis (PN 39083)	1
15	Screw, Socket Head Cap, M6 × 1 - 30 (PN 30353)	4
16	Screw, Socket Head Cap, M5 × 0.8 - 8 (PN 30844)	2
17	Nut, Hex, M5 × 0.8 (PN 31201)	2

DRAWINGS

IN THIS SECTION, YOU'LL LEARN:

- About various component specifications for this machine.

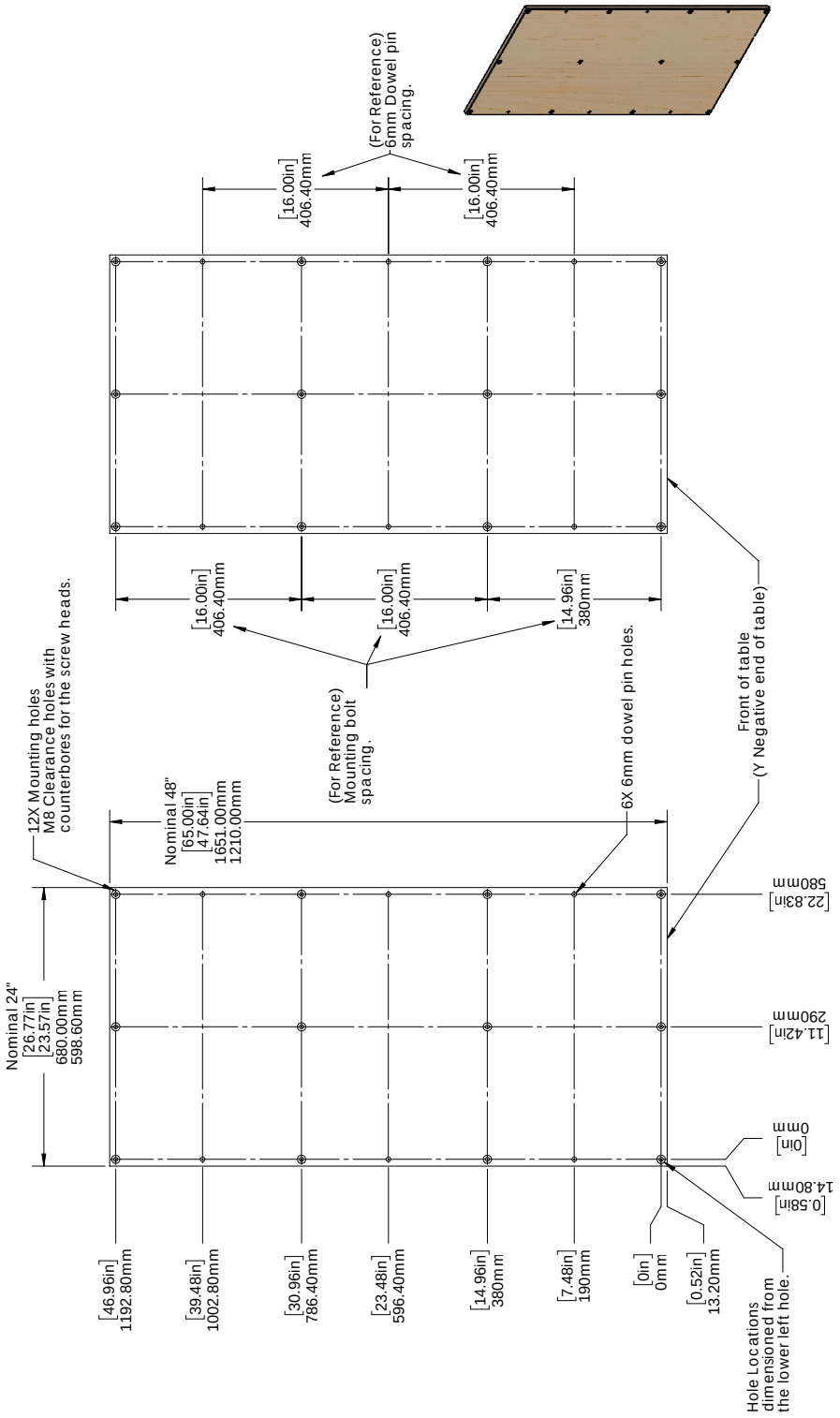
CONTENTS

13: DRAWINGS

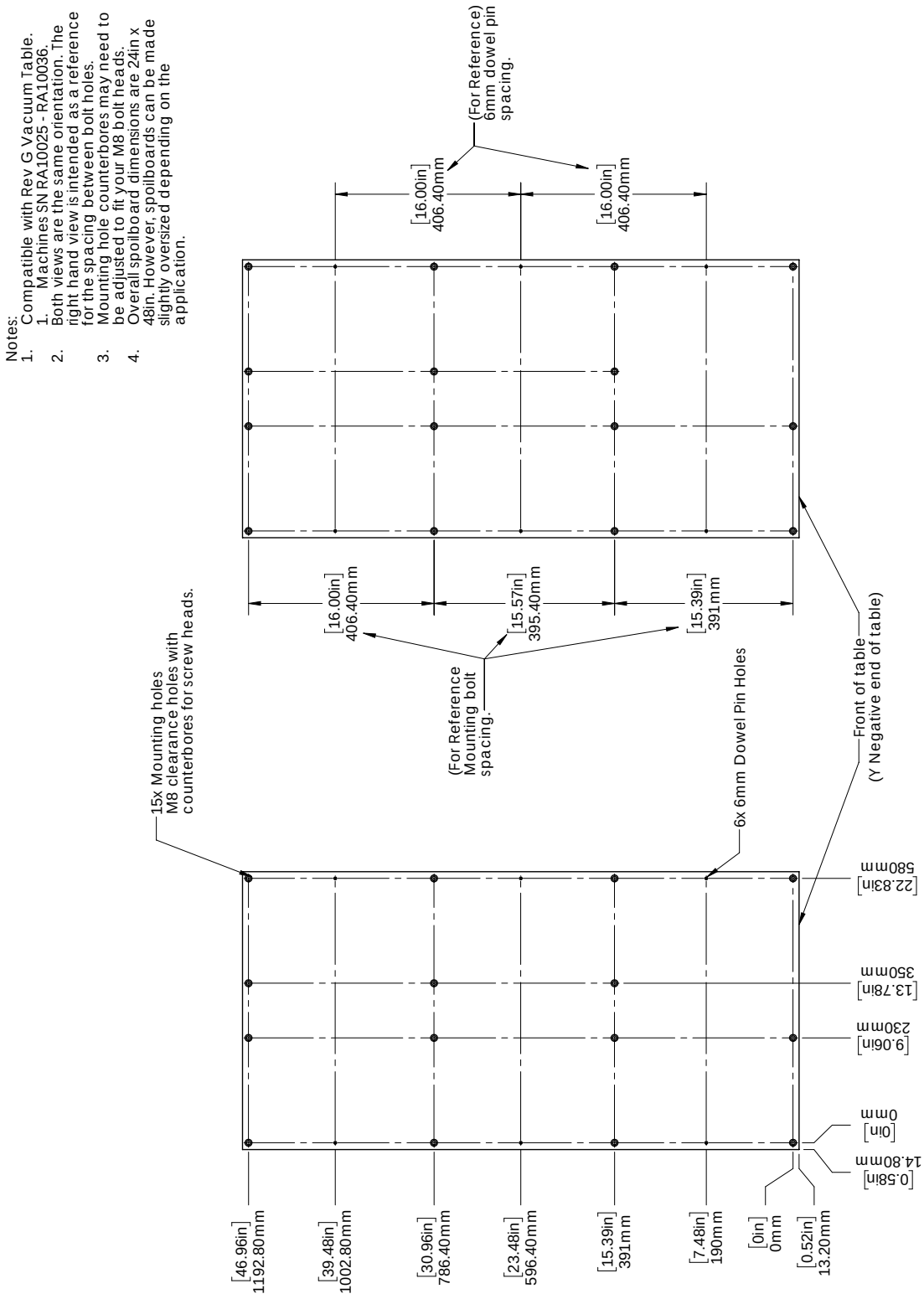
13.1 SPOILBOARD BOLT PATTERN

The spoilboard bolt pattern varies by serial number. Identify your machine's serial number (on the side of the electrical cabinet, near the Main Disconnect switch), and then refer to one of the following drawings.

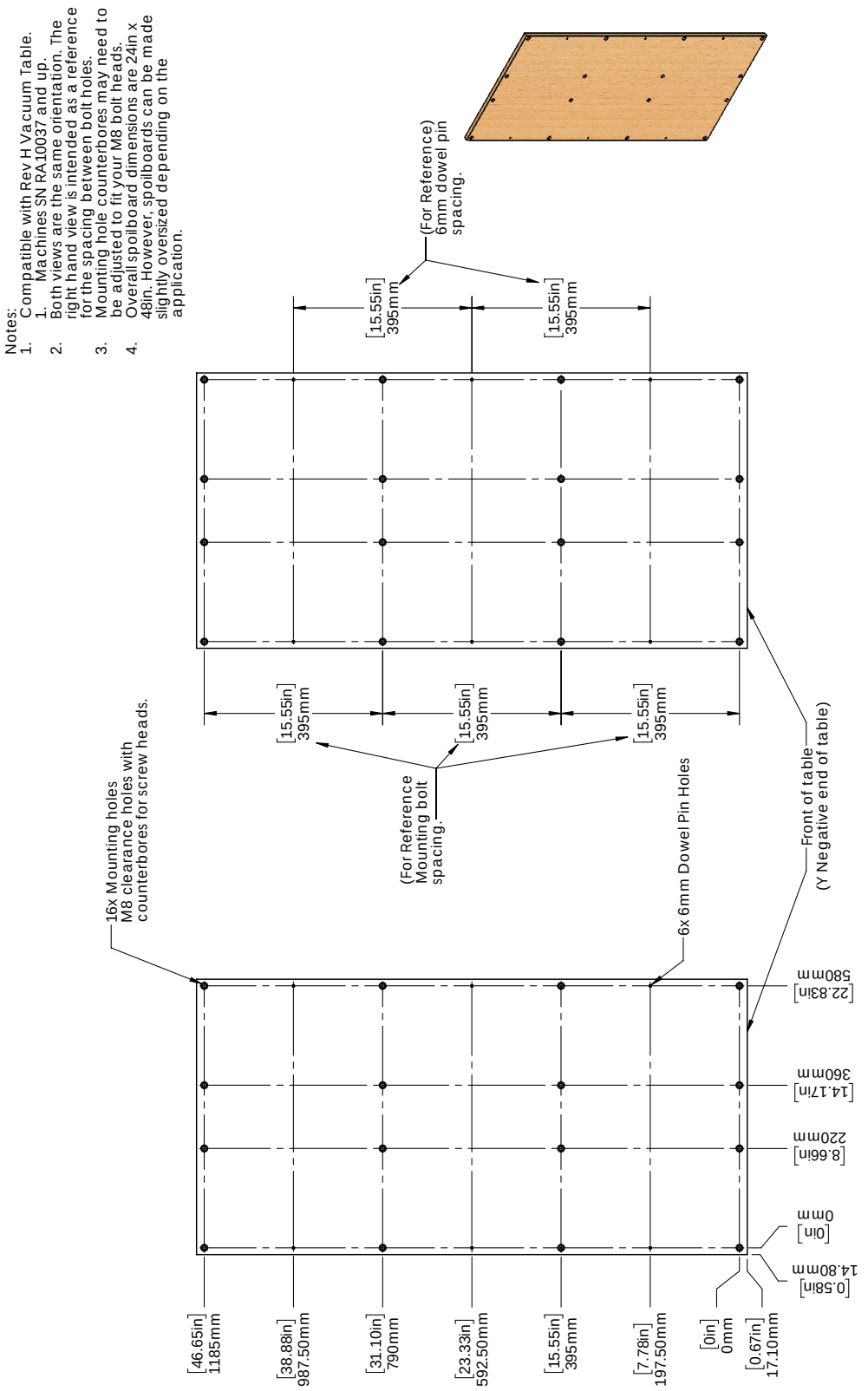
13.1.1 RA10001 through RA10024



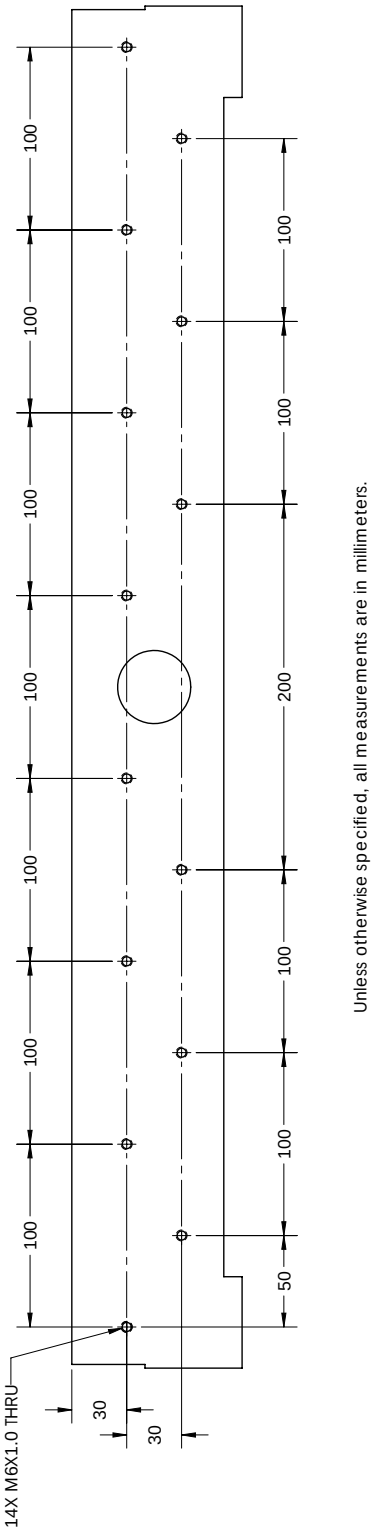
13.1.2 RA10025 through RA10036



13.1.3 RA10037 and Higher

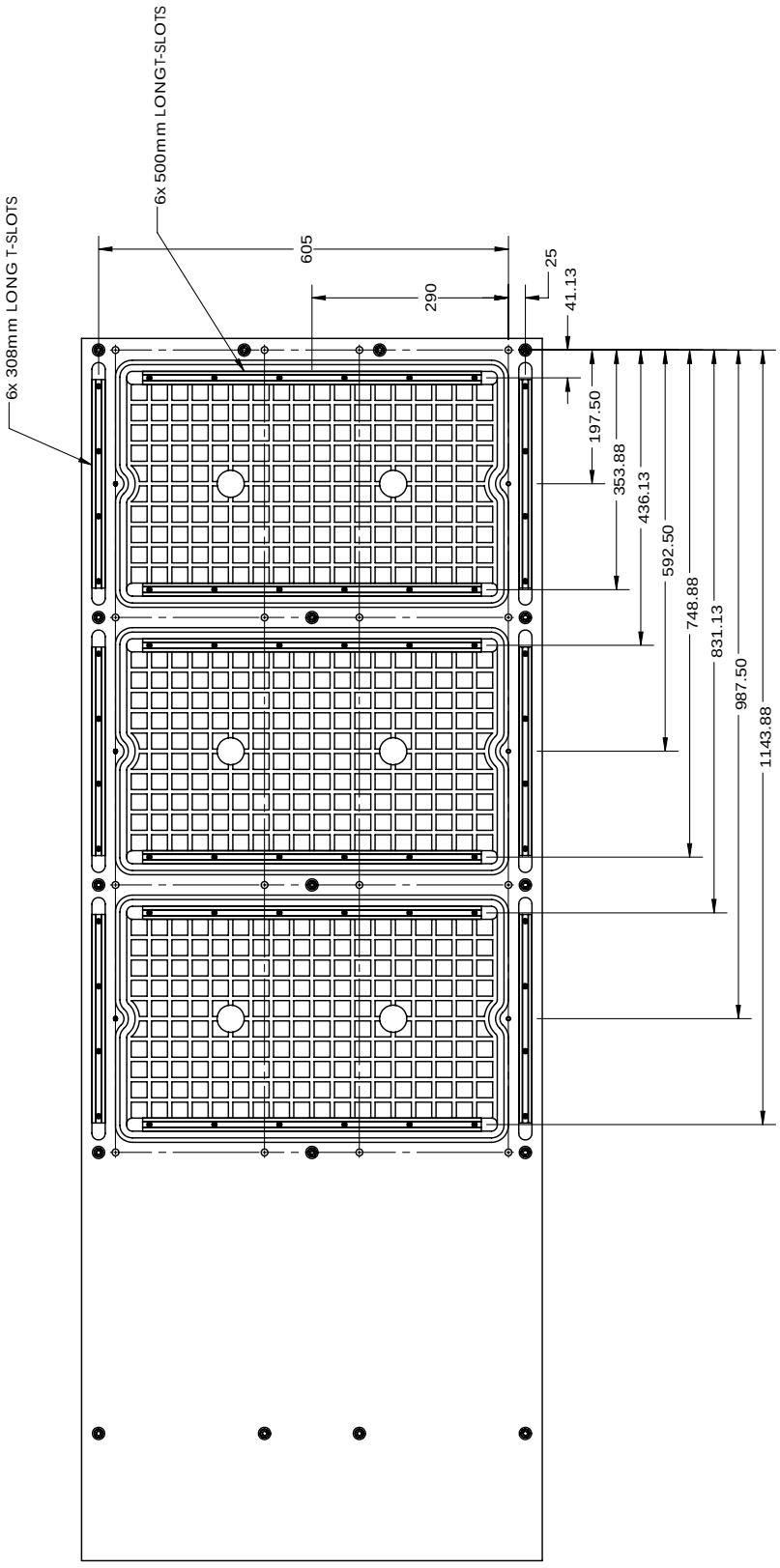


13.2 VERTICAL FIXTURING HOLE PATTERN



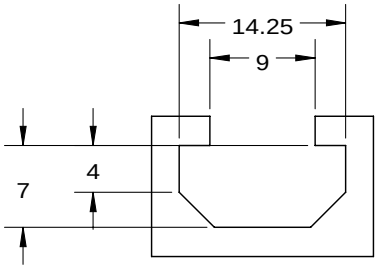
13.3 T-SLOT LAYOUT

13.3.1 RA10037 and Higher



13.4 T-SLOT DIMENSIONS

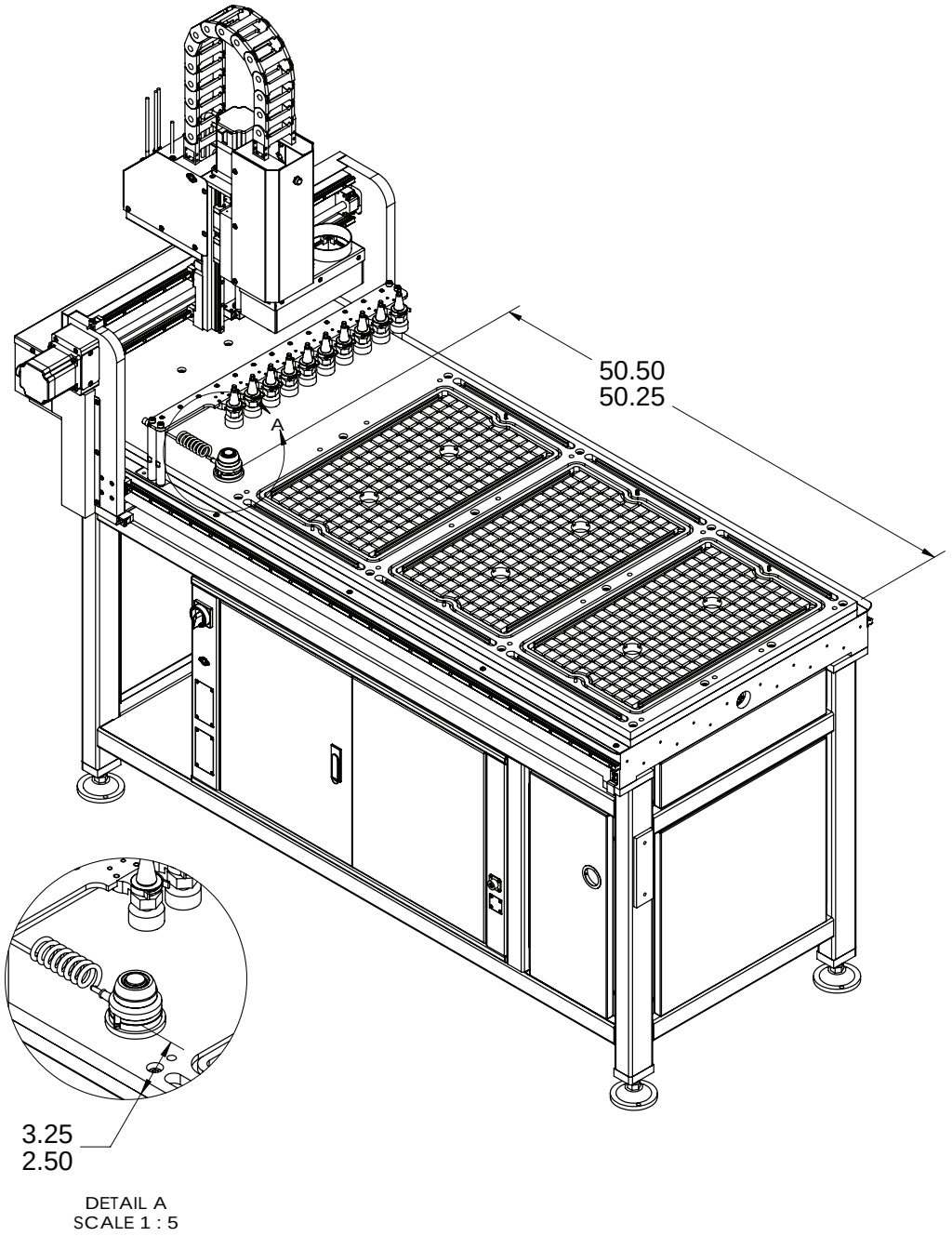
13.4.1 RA10037 and Higher

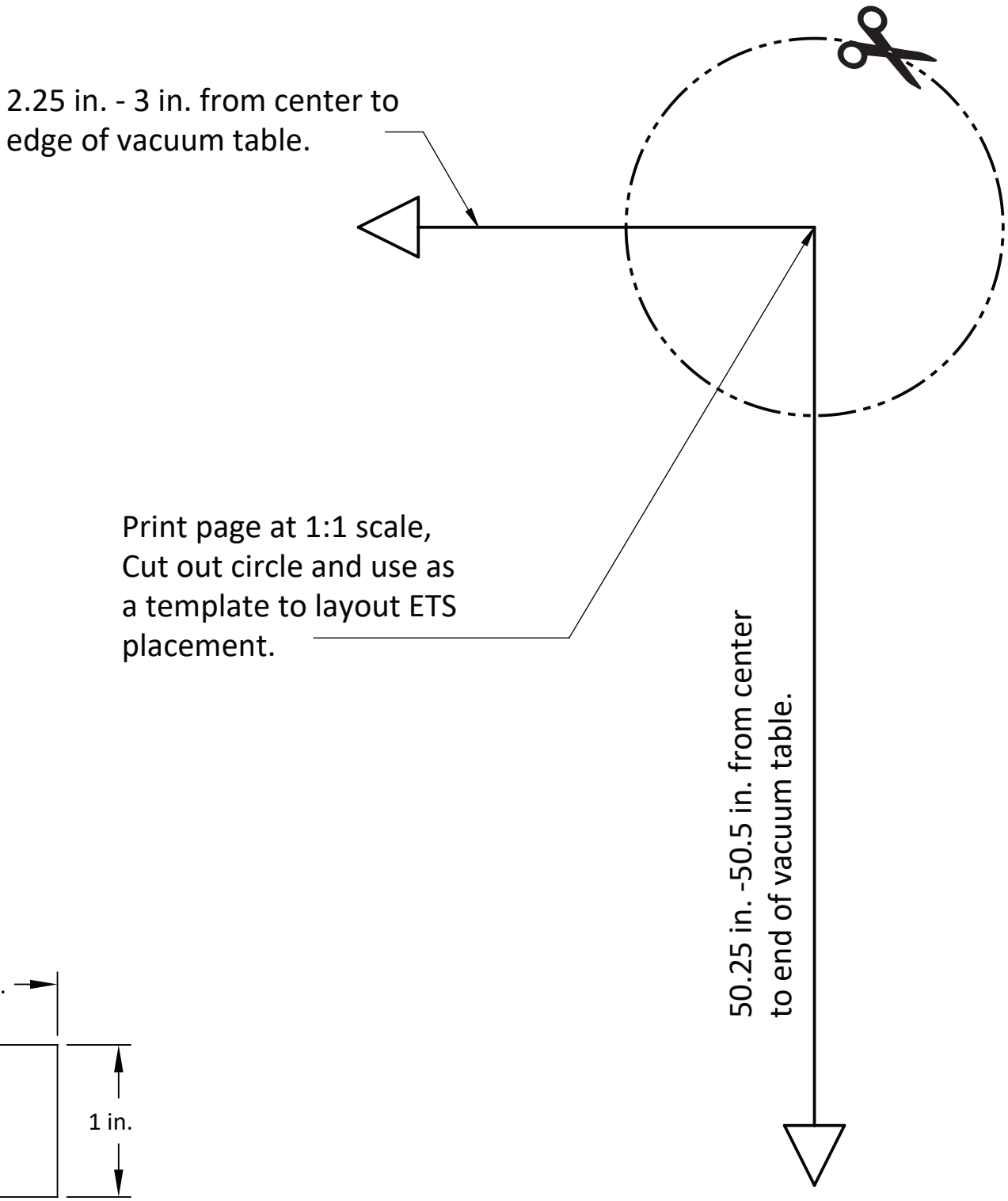


FITS MOST 1/4" - 20 AND 5/16" - 18 T-BOLTS

13.5 ETS PLACEMENT LAYOUT

Use the drawing below and the template on the following page to determine the placement for the Electronic Tool Setter (ETS) on your machine.





KEY

Measure the square (above) to confirm that this drawing is printed to scale. If the square is not accurate in both X and Y, reprint this drawing on a 1:1 scale.

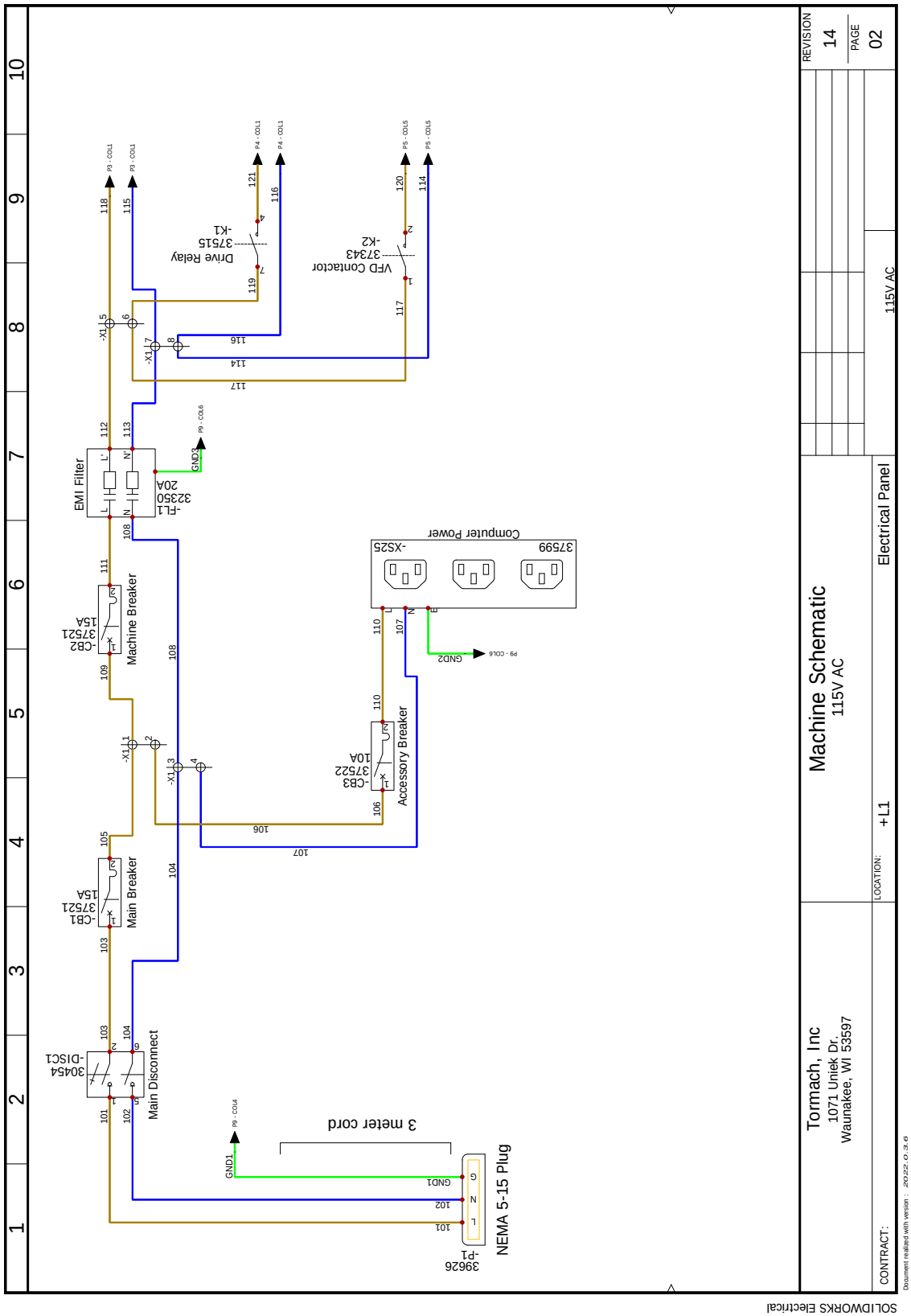
ELECTRICAL SCHEMATICS

IN THIS SECTION, YOU'LL LEARN:

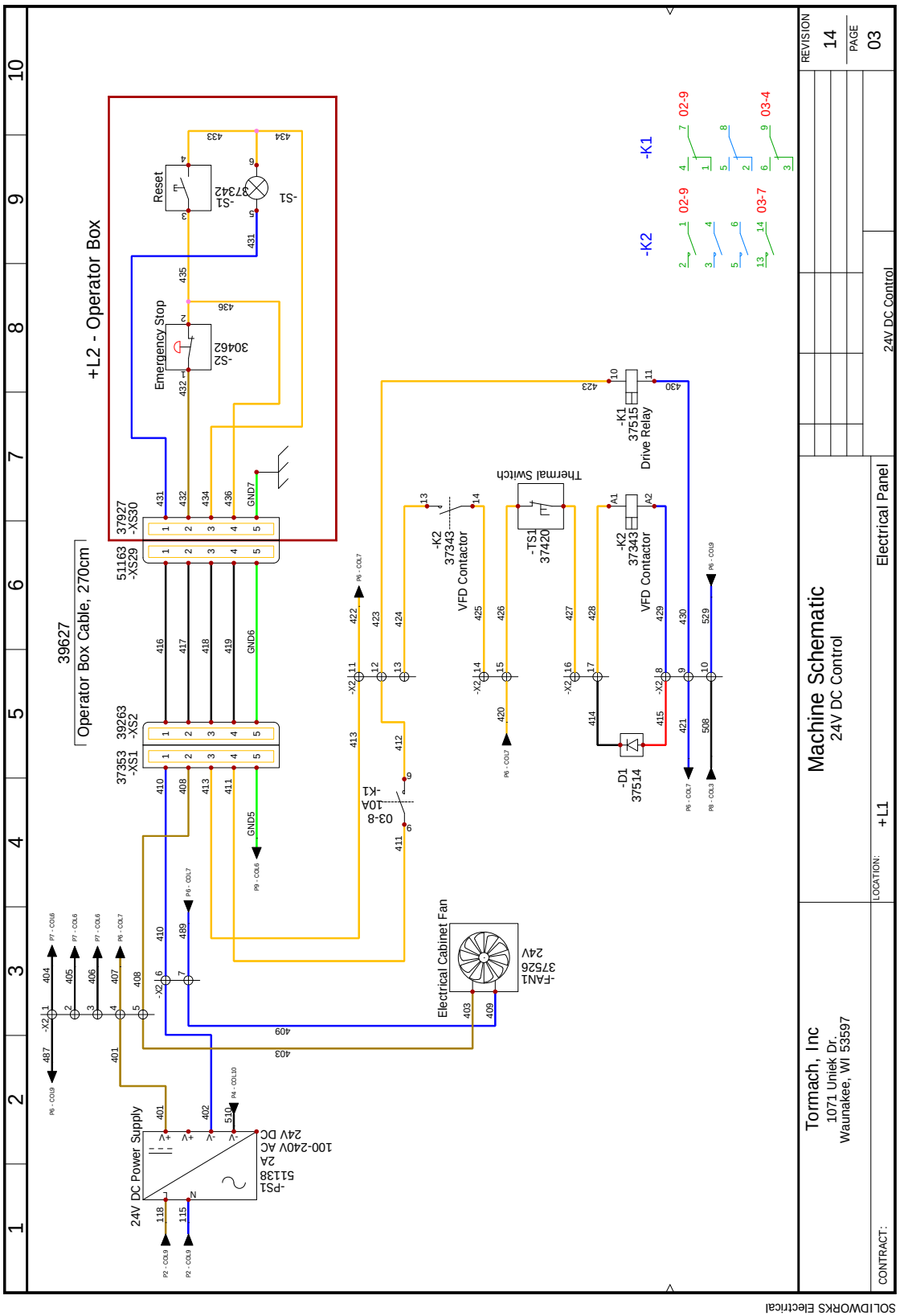
- About the electrical schematics for this machine's electronics.

CONTENTS

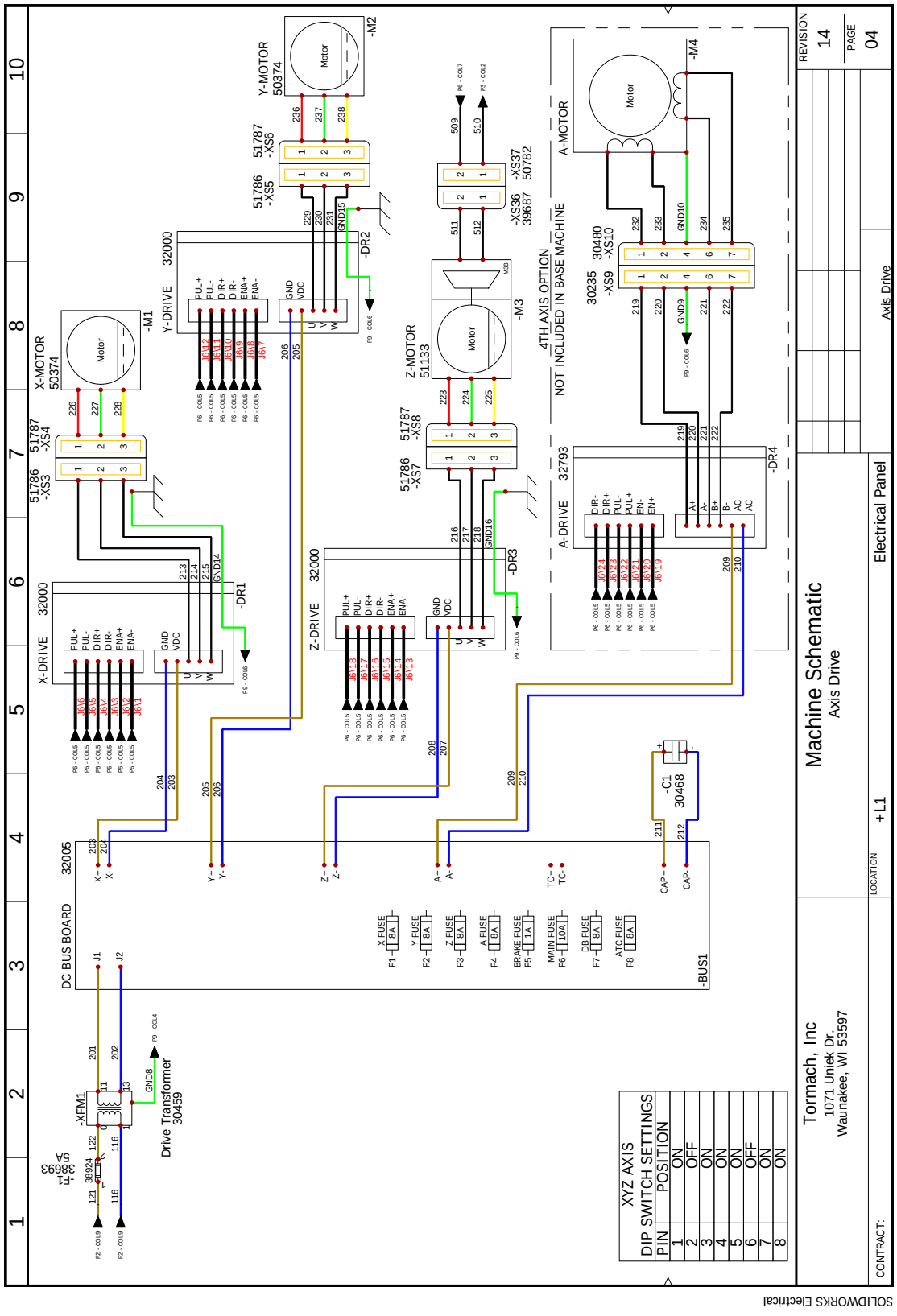
14.1 115 VAC POWER (SHEET 2)



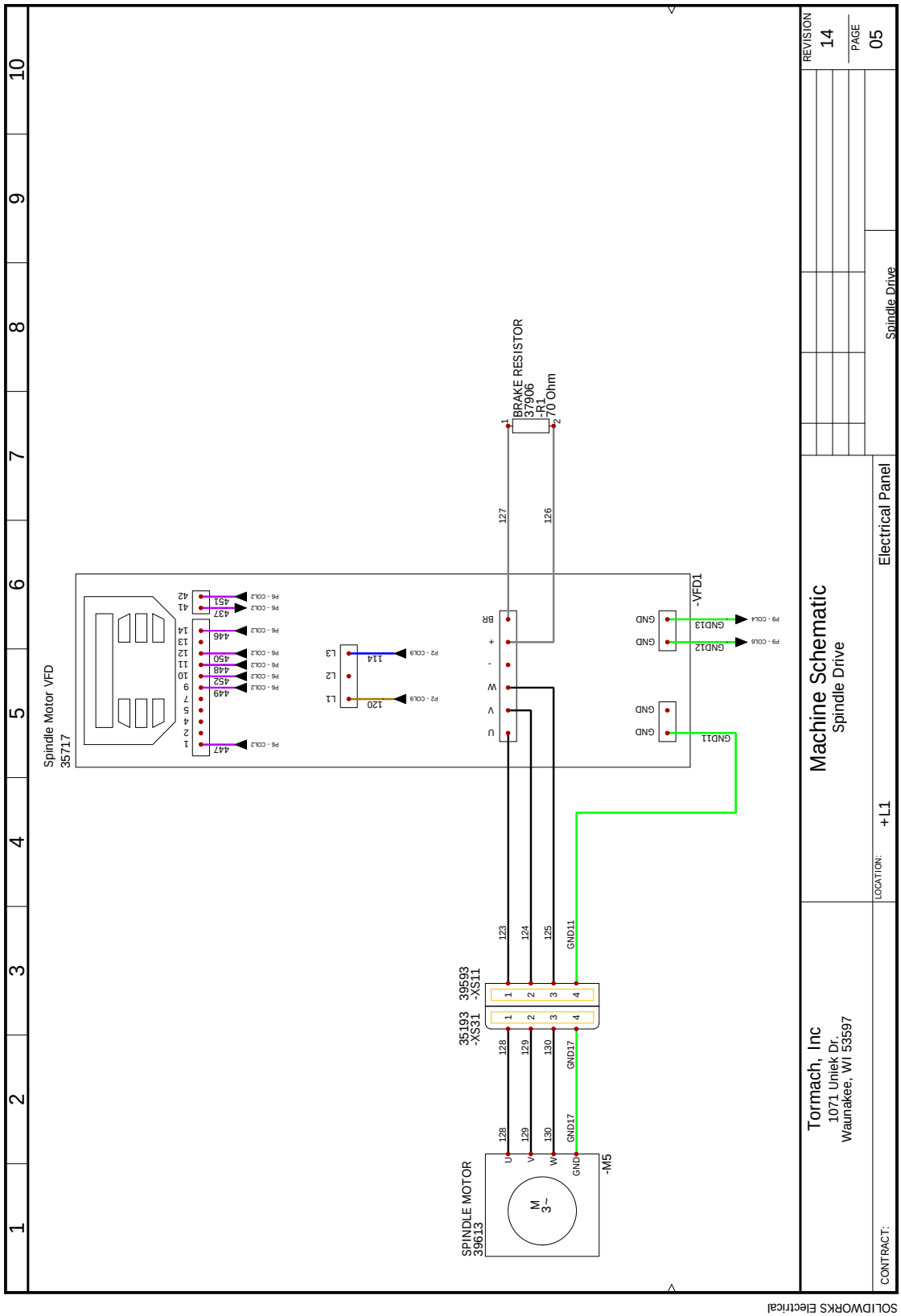
14.2 24 VDC CONTROLS (SHEET 3)



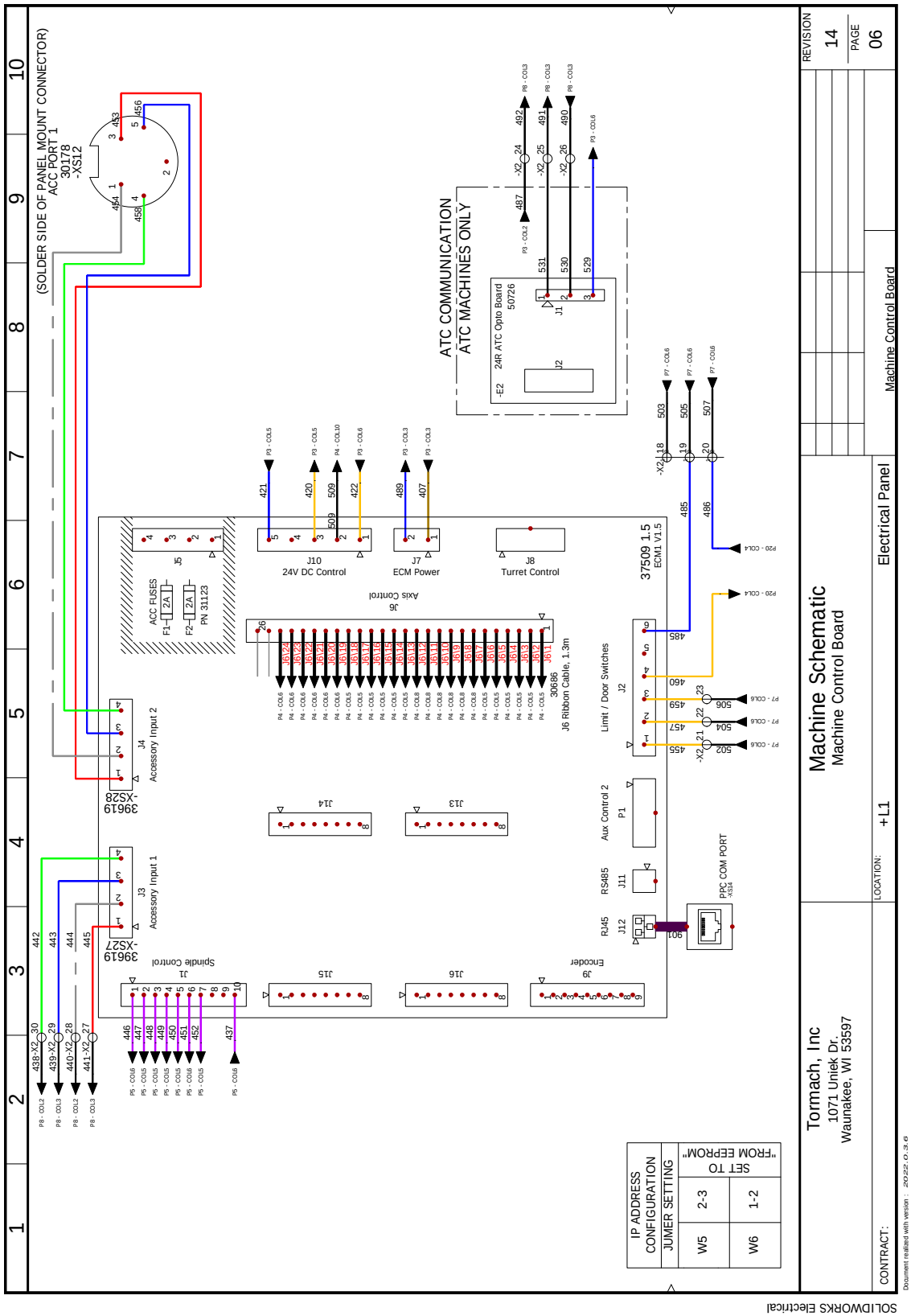
14.3 AXIS DRIVE BUS (SHEET 4)



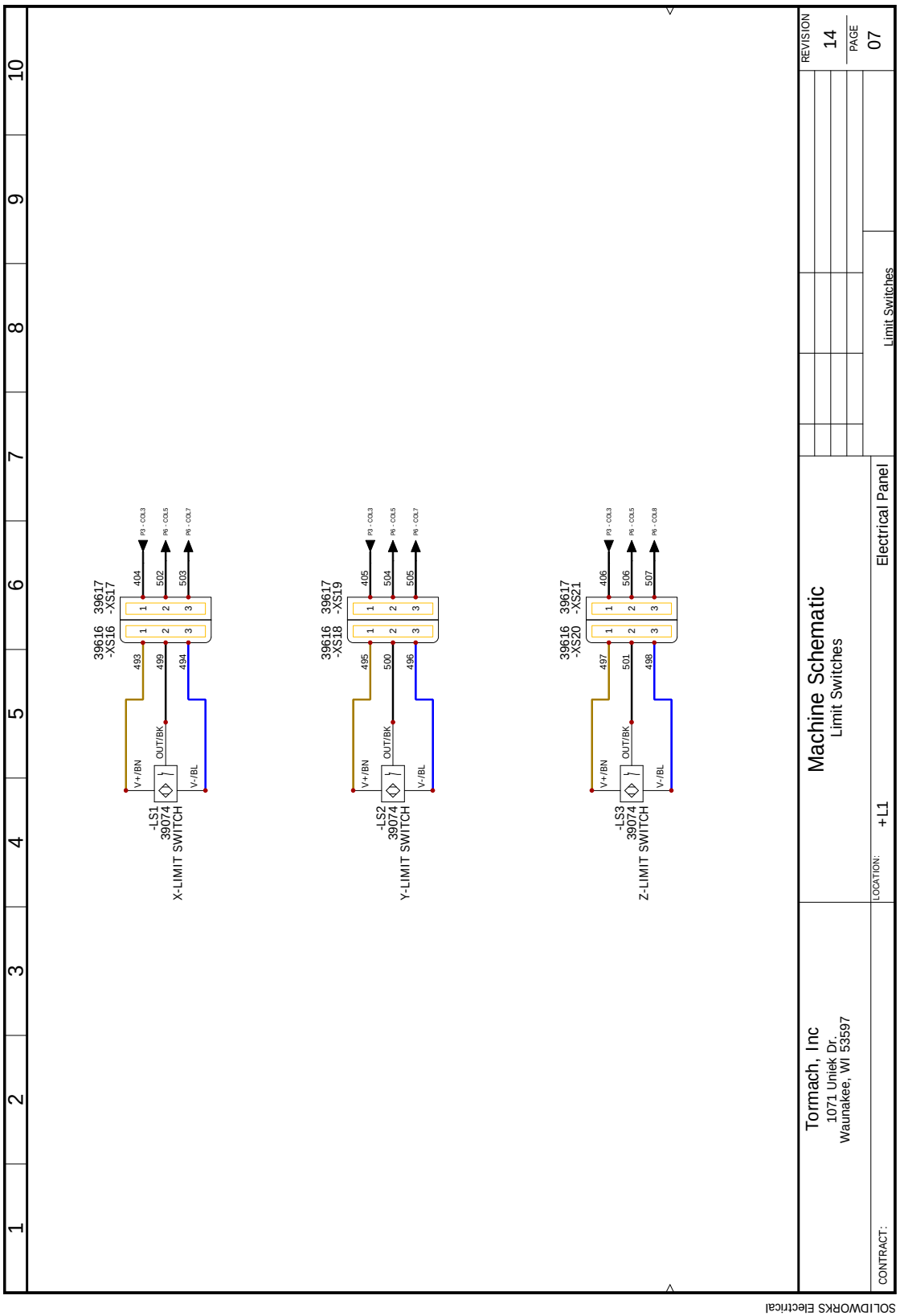
14.4 SPINDLE DRIVE (SHEET 5)



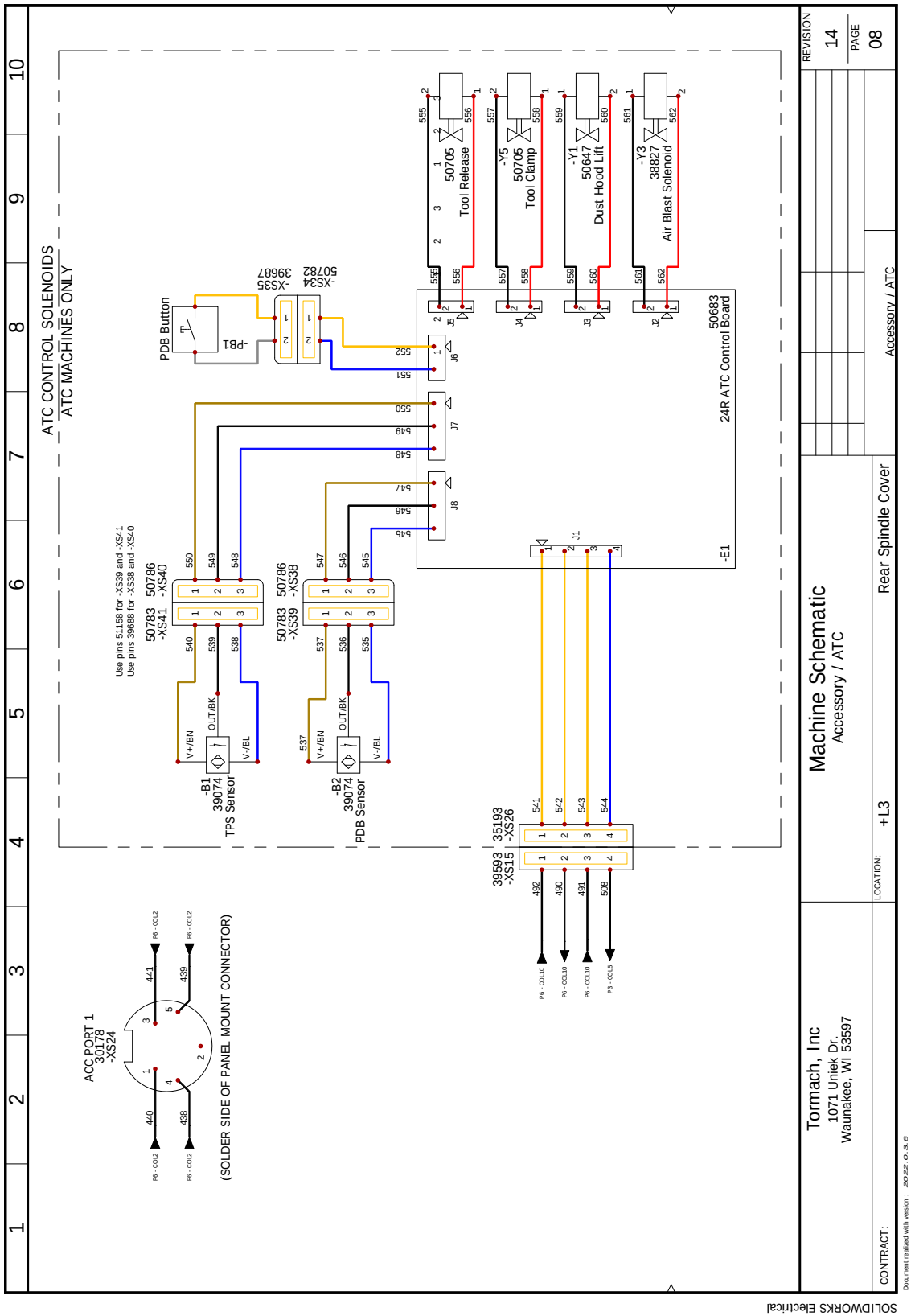
14.5 MACHINE CONTROL BOARD (SHEET 6)



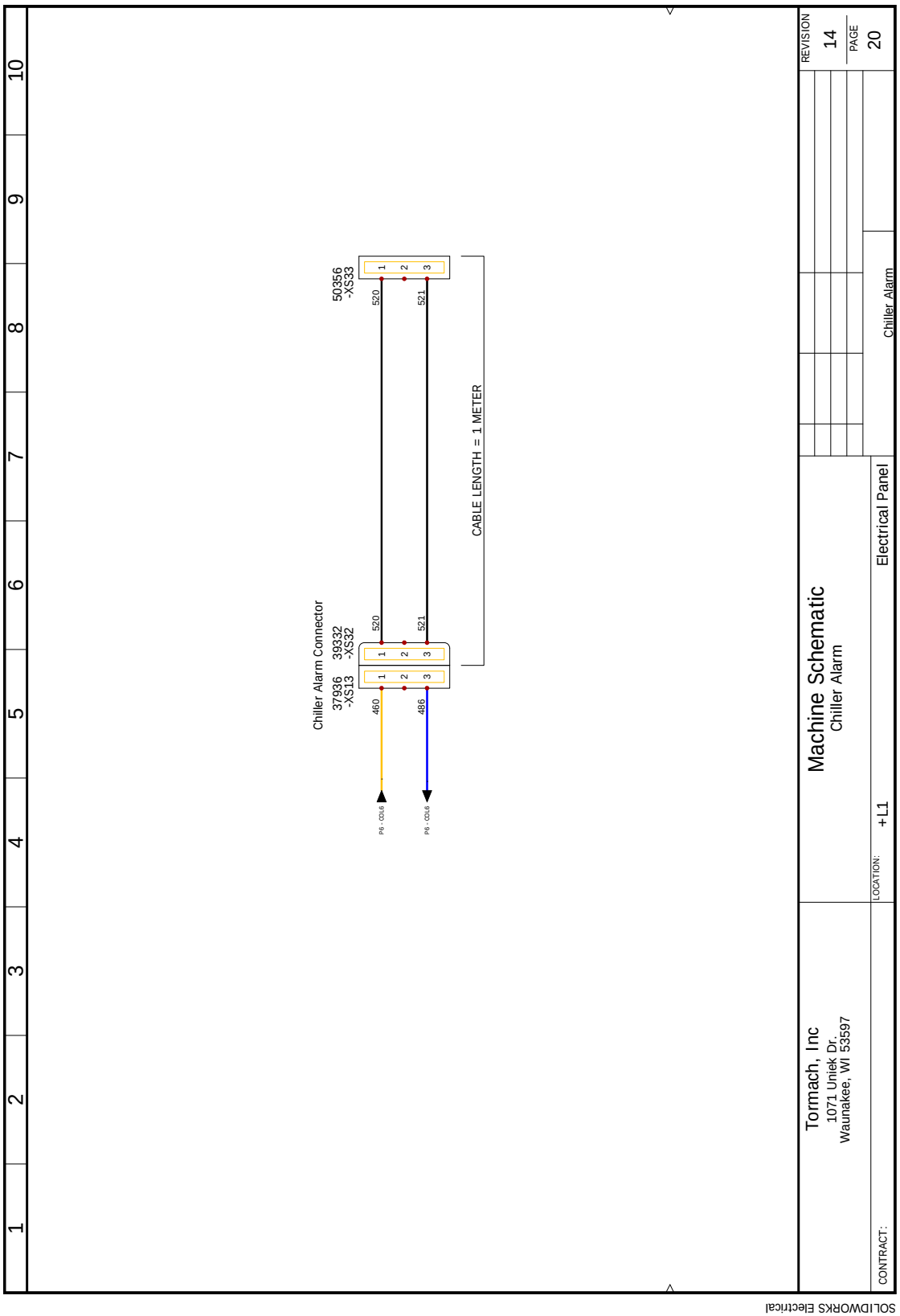
14.6 LIMIT SWITCHES (SHEET 7)



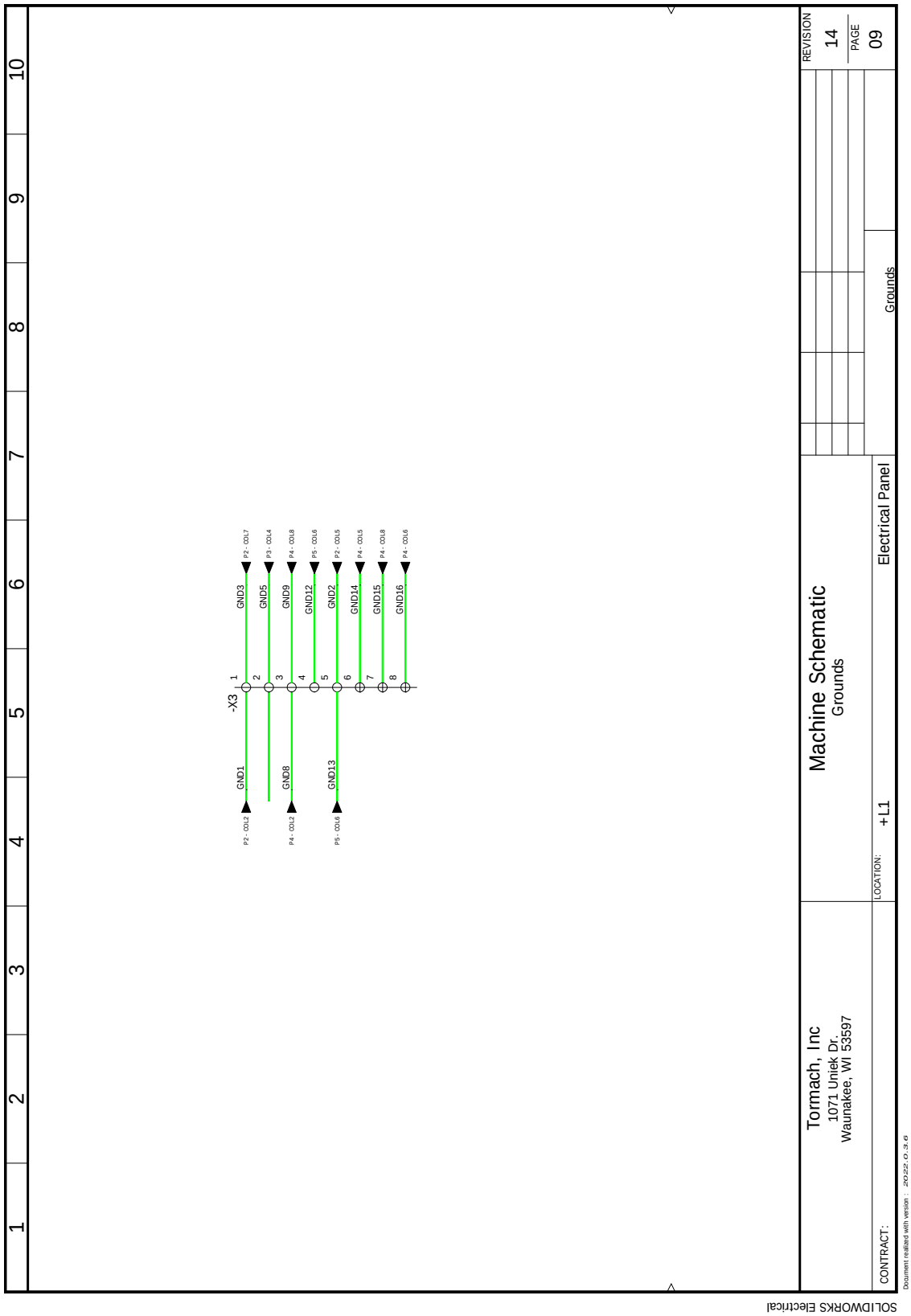
14.7 ACCESSORY AND AUXILIARY POWER (SHEET 8)



14.8 CHILLER ALARM (SHEET 9)

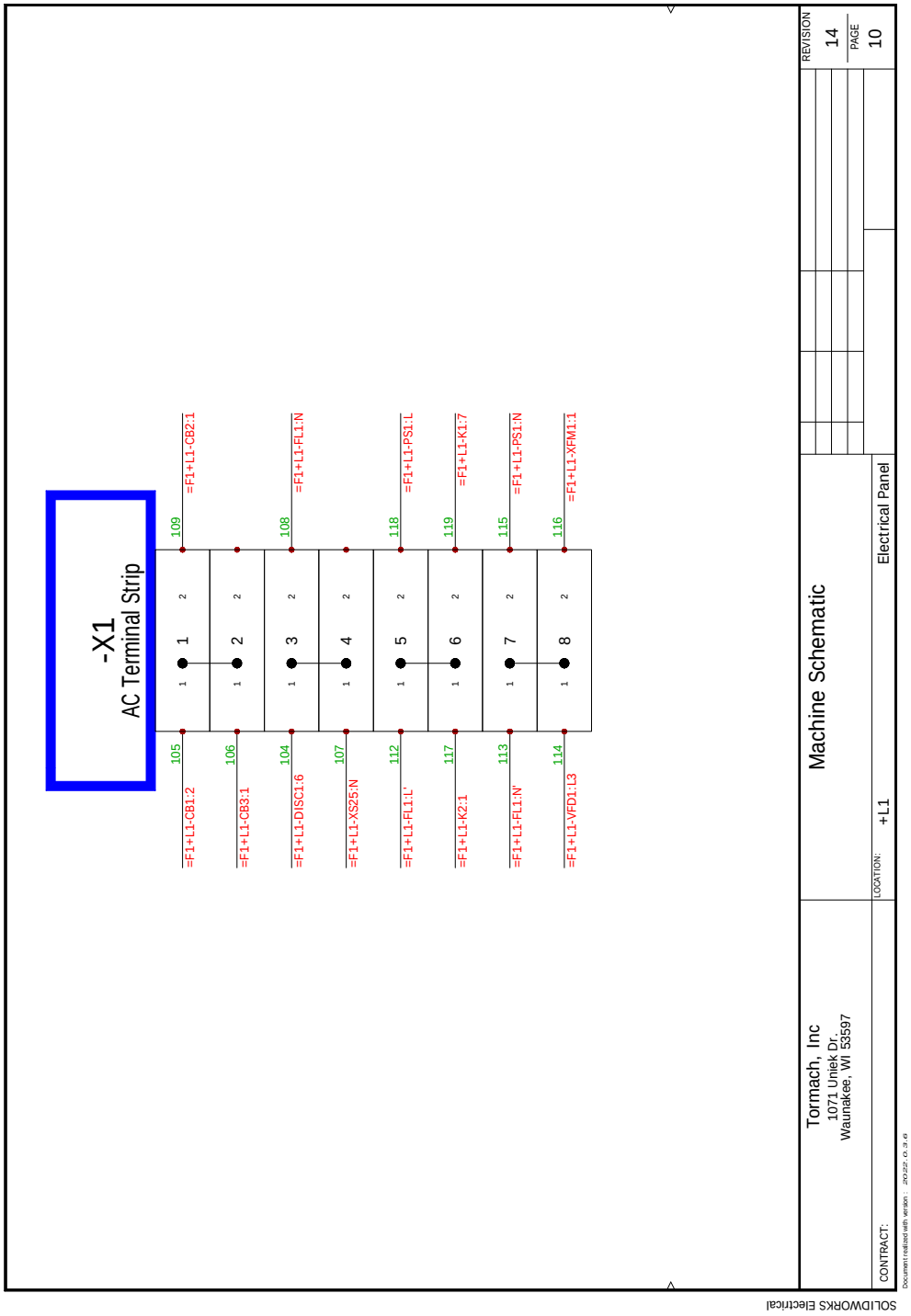


14.9 GROUNDS (SHEET 10)

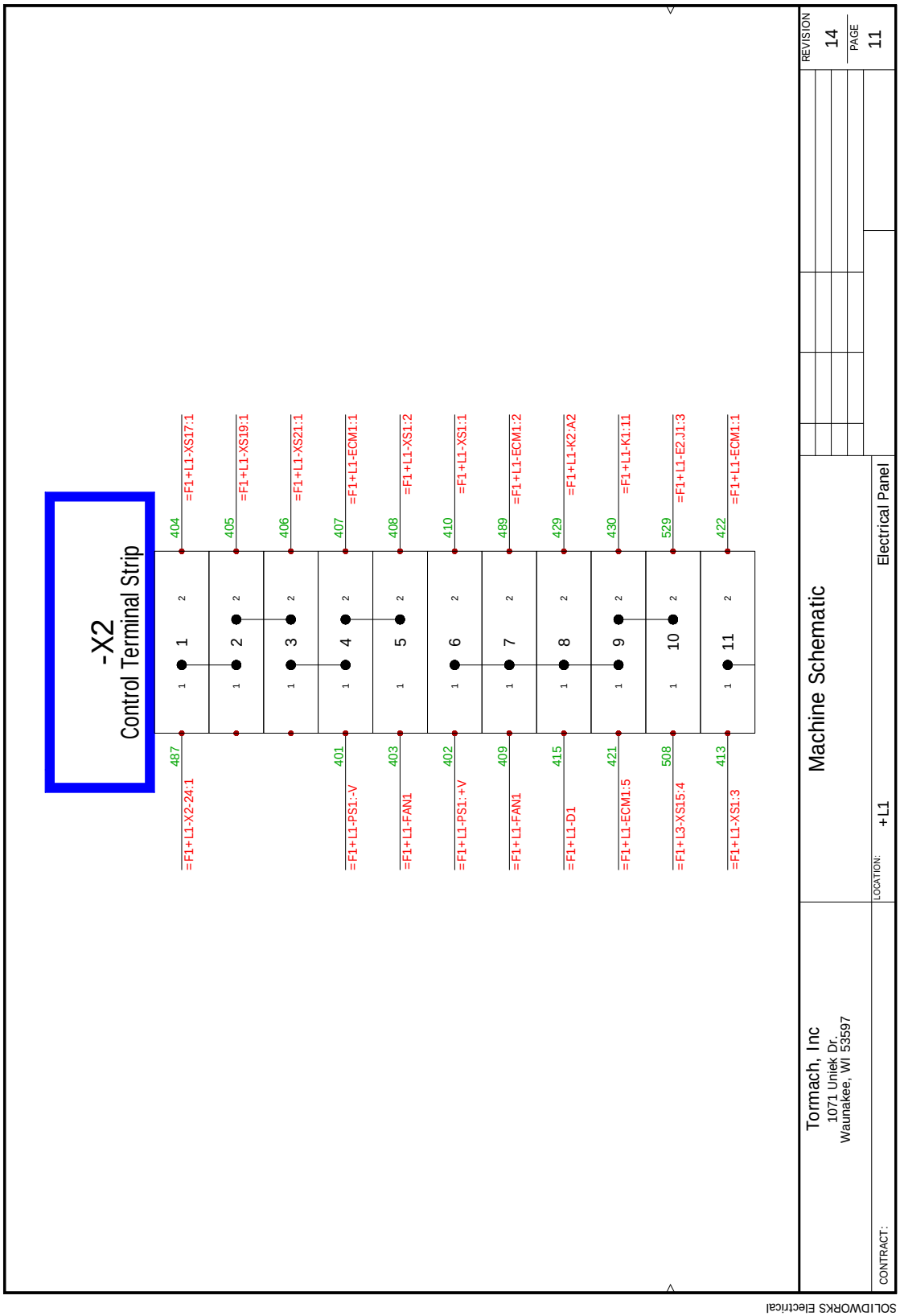


14.10 TERMINAL STRIPS (SHEETS 11-16)

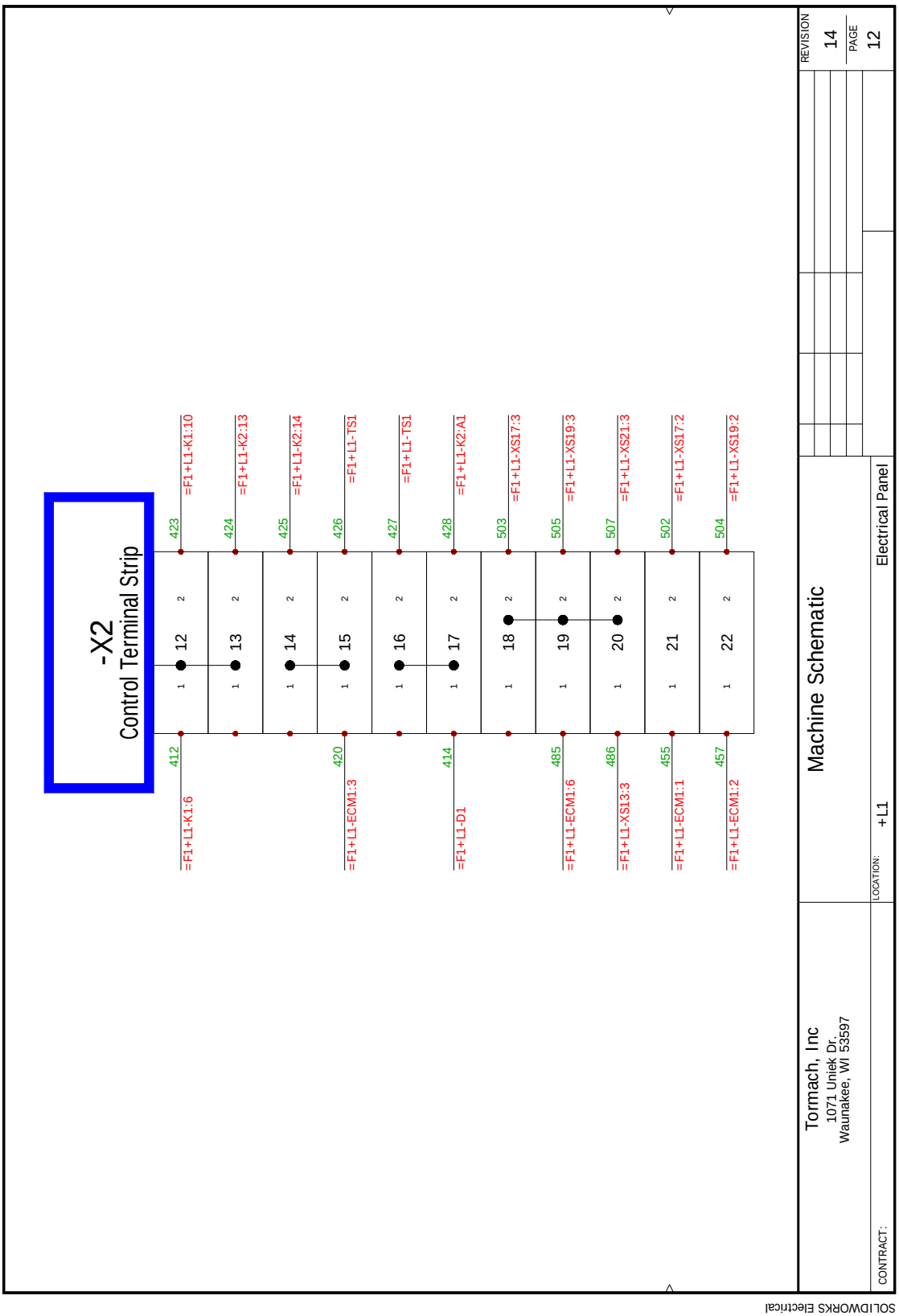
14.10.1 X1: AC Terminal Strip (Sheet 11)



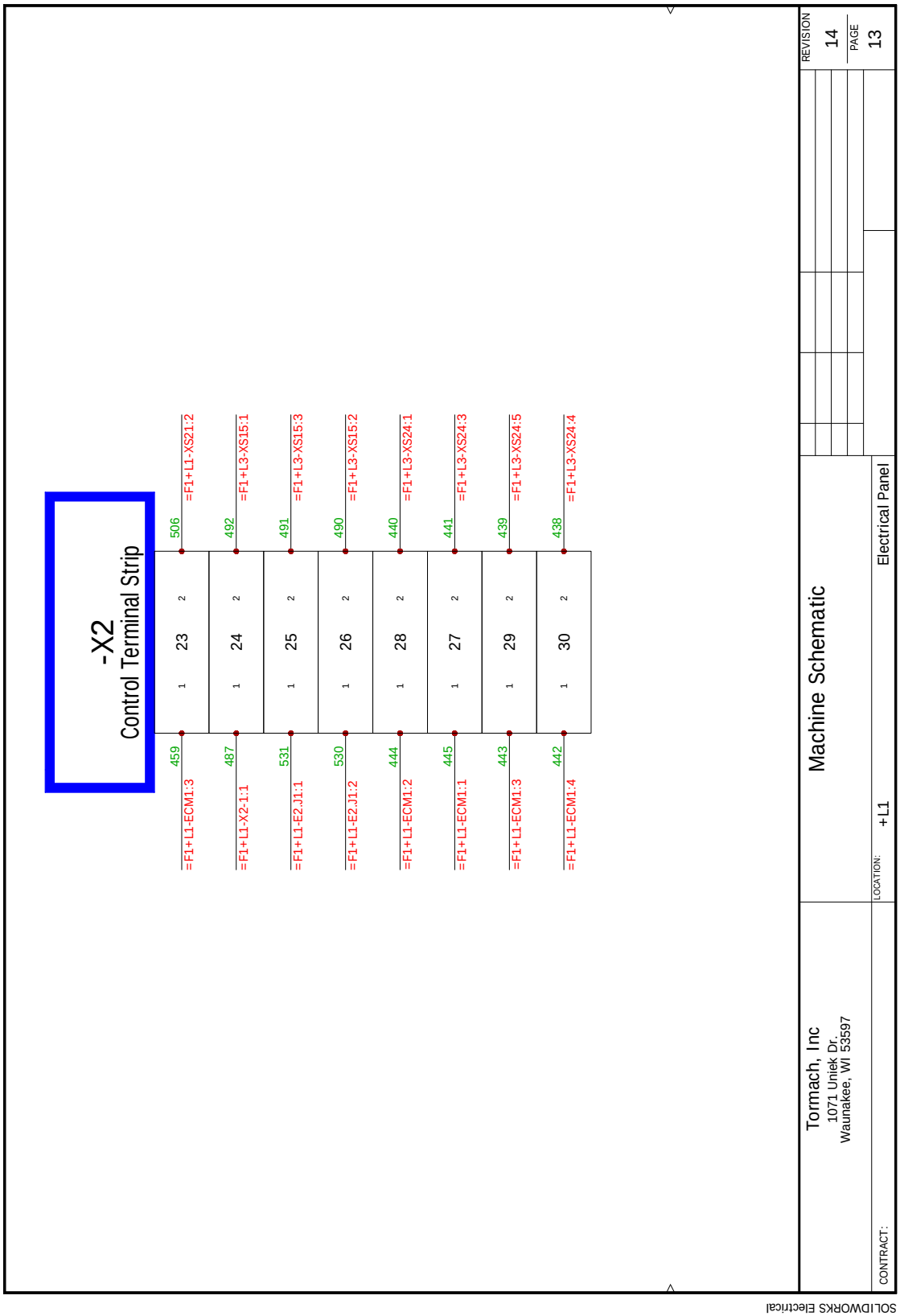
14.10.2 X2: Control Terminal Strip (Sheet 12)



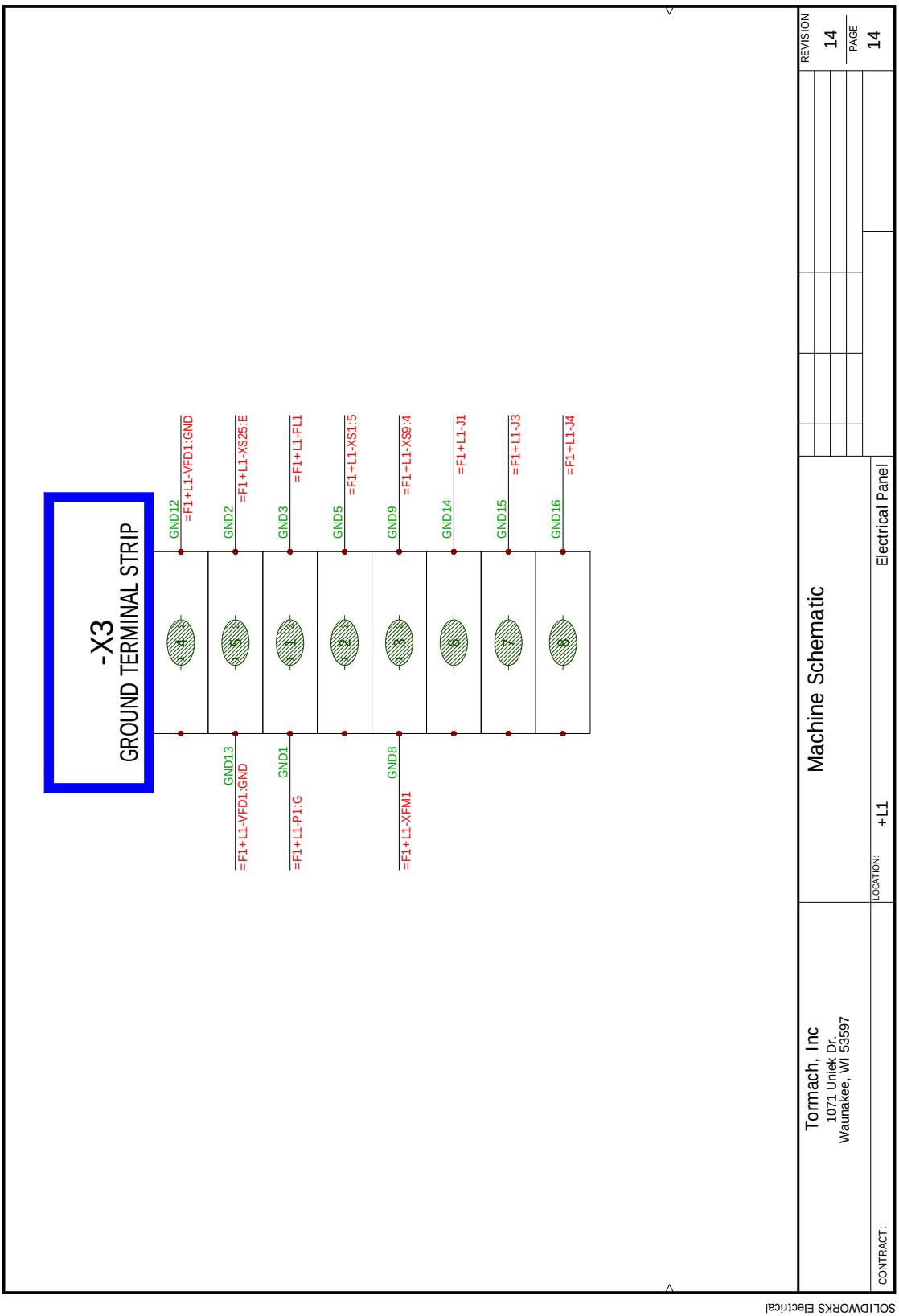
14.10.3 X2: Control Terminal Strip (Sheet 13)



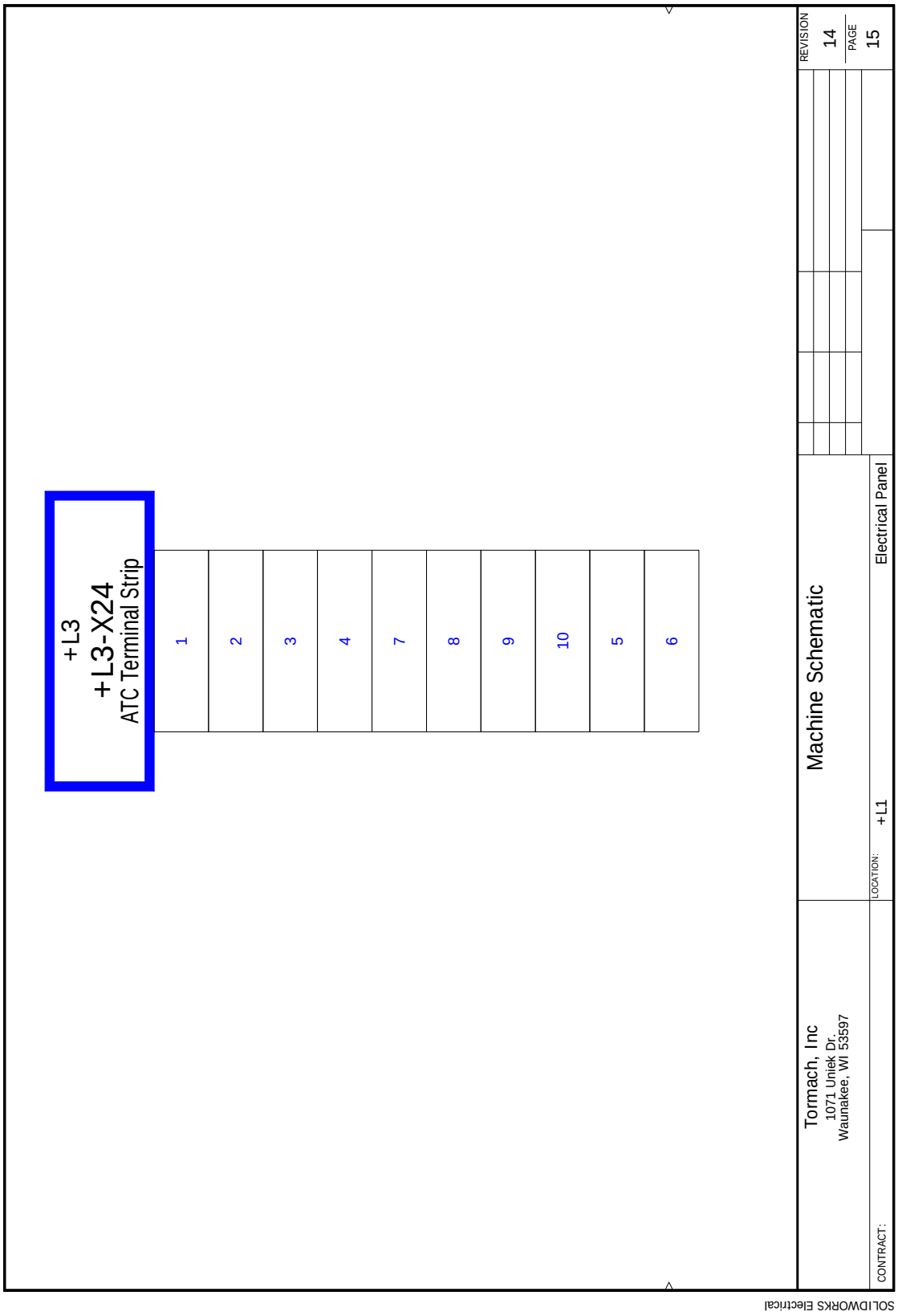
14.10.4 X2: Control Terminal Strip (Sheet 14)



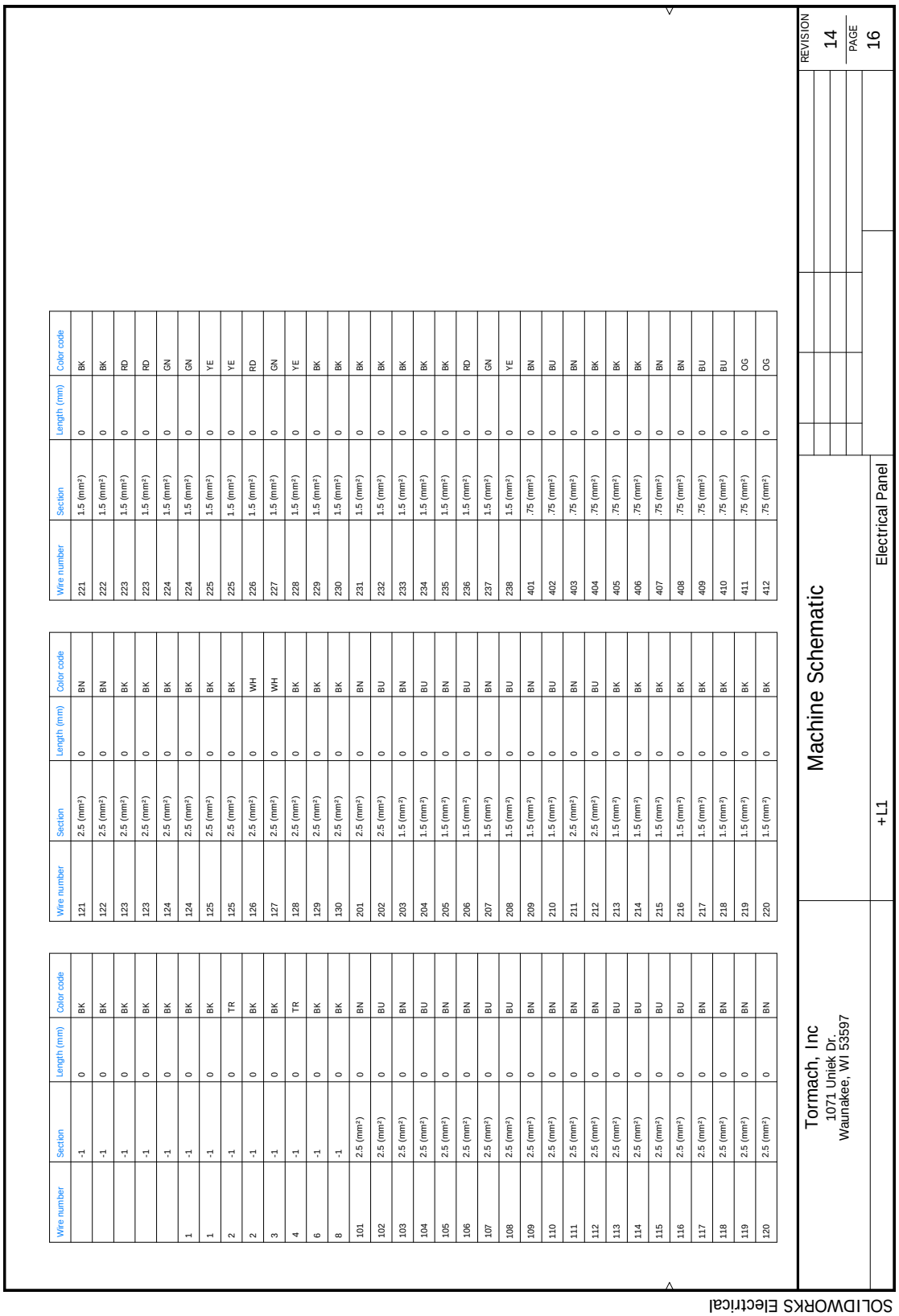
14.10.5 X3: Ground Terminal Strip (Sheet 15)



14.10.6 X24: ATC Terminal Strip (Sheet 16)



14.11 WIRING TABLE (SHEETS 17-19)



Wire number	Section	Length (mm)	Color code
	-1	0	BK
	-1	0	BK
	-1	0	BK
	-1	0	BK
	-1	0	BK
1	-1	0	BK
1	-1	0	BK
2	-1	0	TR
2	-1	0	BK
3	-1	0	BK
4	-1	0	TR
6	-1	0	BK
8	-1	0	BK
101	2.5 (mm²)	0	BN
102	2.5 (mm²)	0	BU
103	2.5 (mm²)	0	BN
104	2.5 (mm²)	0	BU
105	2.5 (mm²)	0	BN
106	2.5 (mm²)	0	BN
107	2.5 (mm²)	0	BU
108	2.5 (mm²)	0	BU
109	2.5 (mm²)	0	BN
110	2.5 (mm²)	0	BN
111	2.5 (mm²)	0	BN
112	2.5 (mm²)	0	BN
113	2.5 (mm²)	0	BU
114	2.5 (mm²)	0	BU
115	2.5 (mm²)	0	BU
116	2.5 (mm²)	0	BU
117	2.5 (mm²)	0	BN
118	2.5 (mm²)	0	BN
119	2.5 (mm²)	0	BN
120	2.5 (mm²)	0	BN

Wire number	Section	Length (mm)	Color code
121	2.5 (mm²)	0	BN
122	2.5 (mm²)	0	BN
123	2.5 (mm²)	0	BK
123	2.5 (mm²)	0	BK
124	2.5 (mm²)	0	BK
124	2.5 (mm²)	0	BK
125	2.5 (mm²)	0	BK
125	2.5 (mm²)	0	BK
126	2.5 (mm²)	0	WH
127	2.5 (mm²)	0	WH
128	2.5 (mm²)	0	BK
129	2.5 (mm²)	0	BK
130	2.5 (mm²)	0	BK
201	2.5 (mm²)	0	BN
202	2.5 (mm²)	0	BU
203	1.5 (mm²)	0	BN
204	1.5 (mm²)	0	BU
205	1.5 (mm²)	0	BN
206	1.5 (mm²)	0	BU
207	1.5 (mm²)	0	BN
208	1.5 (mm²)	0	BU
209	1.5 (mm²)	0	BN
210	1.5 (mm²)	0	BU
211	2.5 (mm²)	0	BN
212	2.5 (mm²)	0	BU
213	1.5 (mm²)	0	BK
214	1.5 (mm²)	0	BK
215	1.5 (mm²)	0	BK
216	1.5 (mm²)	0	BK
217	1.5 (mm²)	0	BK
218	1.5 (mm²)	0	BK
219	1.5 (mm²)	0	BK
220	1.5 (mm²)	0	BK

Wire number	Section	Length (mm)	Color code
221	1.5 (mm²)	0	BK
222	1.5 (mm²)	0	BK
223	1.5 (mm²)	0	RD
223	1.5 (mm²)	0	RD
224	1.5 (mm²)	0	GN
224	1.5 (mm²)	0	GN
225	1.5 (mm²)	0	YE
225	1.5 (mm²)	0	YE
226	1.5 (mm²)	0	RD
227	1.5 (mm²)	0	GN
228	1.5 (mm²)	0	YE
229	1.5 (mm²)	0	BK
230	1.5 (mm²)	0	BK
231	1.5 (mm²)	0	BK
232	1.5 (mm²)	0	BK
233	1.5 (mm²)	0	BK
234	1.5 (mm²)	0	BK
235	1.5 (mm²)	0	BK
236	1.5 (mm²)	0	RD
237	1.5 (mm²)	0	GN
238	1.5 (mm²)	0	YE
401	.75 (mm²)	0	BN
402	.75 (mm²)	0	BU
403	.75 (mm²)	0	BN
404	.75 (mm²)	0	BK
405	.75 (mm²)	0	BK
406	.75 (mm²)	0	BK
407	.75 (mm²)	0	BN
408	.75 (mm²)	0	BN
409	.75 (mm²)	0	BU
410	.75 (mm²)	0	BU
411	.75 (mm²)	0	OG
412	.75 (mm²)	0	OG

Wire number	Section	Length (mm)	Color code
413	.75 (mm²)	0	OG
414	.75 (mm²)	0	BK
415	.75 (mm²)	0	RD
416	.75 (mm²)	0	BK
417	.75 (mm²)	0	BK
418	.75 (mm²)	0	BK
419	.75 (mm²)	0	BK
420	.75 (mm²)	0	OG
421	.75 (mm²)	0	BU
422	.75 (mm²)	0	OG
423	.75 (mm²)	0	OG
424	.75 (mm²)	0	OG
425	.75 (mm²)	0	OG
426	.75 (mm²)	0	OG
427	.75 (mm²)	0	OG
428	.75 (mm²)	0	OG
429	.75 (mm²)	0	BU
430	.75 (mm²)	0	BU
431	.75 (mm²)	0	BU
432	.75 (mm²)	0	BN
433	.75 (mm²)	0	OG
434	.75 (mm²)	0	OG
435	.75 (mm²)	0	OG
436	.75 (mm²)	0	OG
437	.75 (mm²)	0	VT
438	.75 (mm²)	0	BK
439	.75 (mm²)	0	BK
440	.75 (mm²)	0	BK
441	.75 (mm²)	0	BK
442	.2 (mm²)	0	GN
443	.2 (mm²)	0	BU
444	.2 (mm²)	0	WH
445	.2 (mm²)	0	RD

Wire number	Section	Length (mm)	Color code
446	.75 (mm²)	0	VT
447	.75 (mm²)	0	VT
448	.75 (mm²)	0	VT
449	.75 (mm²)	0	VT
450	.75 (mm²)	0	VT
451	.75 (mm²)	0	VT
452	.75 (mm²)	0	VT
453	.2 (mm²)	0	RD
454	.2 (mm²)	0	WH
455	.75 (mm²)	0	OG
456	.2 (mm²)	0	BU
457	.75 (mm²)	0	OG
458	.2 (mm²)	0	GN
459	.75 (mm²)	0	OG
460	.75 (mm²)	0	OG
485	.75 (mm²)	0	BU
486	.75 (mm²)	0	BU
487	.75 (mm²)	0	BK
489	.75 (mm²)	0	BU
490	.75 (mm²)	0	BK
490	.75 (mm²)	0	BK
491	.75 (mm²)	0	BK
491	.75 (mm²)	0	BK
492	.75 (mm²)	0	BK
492	.75 (mm²)	0	BK
493	.75 (mm²)	0	BN
494	.75 (mm²)	0	BU
495	.75 (mm²)	0	BN
496	.75 (mm²)	0	BU
497	.75 (mm²)	0	BN
498	.75 (mm²)	0	BU
499	.75 (mm²)	0	BK
500	.75 (mm²)	0	BK

Wire number	Section	Length (mm)	Color code
501	.75 (mm²)	0	BK
502	.75 (mm²)	0	BK
503	.75 (mm²)	0	BK
504	.75 (mm²)	0	BK
505	.75 (mm²)	0	BK
506	.75 (mm²)	0	BK
507	.75 (mm²)	0	BK
508	.75 (mm²)	0	BK
508	.75 (mm²)	0	BK
509	.75 (mm²)	0	BK
509	.75 (mm²)	0	BK
510	.75 (mm²)	0	BK
510	.75 (mm²)	0	BK
511	.75 (mm²)	0	BK
511	.75 (mm²)	0	BK
512	.75 (mm²)	0	BK
512	.75 (mm²)	0	BK
520	.75 (mm²)	0	BK
520	.75 (mm²)	0	BK
521	.75 (mm²)	0	BK
521	.75 (mm²)	0	BK
529	.75 (mm²)	0	BU
530	.75 (mm²)	0	BK
531	.75 (mm²)	0	BK
535	.75 (mm²)	0	BU
536	.75 (mm²)	0	BK
537	.75 (mm²)	0	BN
538	.75 (mm²)	0	BU
539	.75 (mm²)	0	BK
540	.75 (mm²)	0	BN
541	.75 (mm²)	0	OG
542	.75 (mm²)	0	OG
543	.75 (mm²)	0	OG

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Wire number	Section	Length (mm)	Color code
544	.75 (mm²)	0	BU
545	.75 (mm²)	0	BU
546	.75 (mm²)	0	BK
547	.75 (mm²)	0	BN
548	.75 (mm²)	0	BU
549	.75 (mm²)	0	BK
550	.75 (mm²)	0	BN
551	.75 (mm²)	0	BU
552	.75 (mm²)	0	OG
554	.75 (mm²)	0	OG
555	.75 (mm²)	0	BK
556	.75 (mm²)	0	RD
557	.75 (mm²)	0	BK
558	.75 (mm²)	0	RD
559	.75 (mm²)	0	BK
560	.75 (mm²)	0	RD
561	.75 (mm²)	0	BK
562	.75 (mm²)	0	RD
563	.75 (mm²)	0	WH
901	-1	0	
GND1	2.5 (mm²)	0	GNYE
GND2	2.5 (mm²)	0	GNYE
GND3	2.5 (mm²)	0	GNYE
GND5	2.5 (mm²)	0	GNYE
GND6	2.5 (mm²)	0	GNYE
GND7	2.5 (mm²)	0	GNYE
GND8	2.5 (mm²)	0	GNYE
GND9	2.5 (mm²)	0	GNYE
GND10	2.5 (mm²)	0	GNYE
GND11	2.5 (mm²)	0	GNYE
GND11	2.5 (mm²)	0	GNYE
GND12	2.5 (mm²)	0	GNYE
GND13	2.5 (mm²)	0	GNYE

Wire number	Section	Length (mm)	Color code
GND14	1.5 (mm²)	0	GNYE
GND15	1.5 (mm²)	0	GNYE
GND16	1.5 (mm²)	0	GNYE
GND17	2.5 (mm²)	0	GNYE
		0	

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Waunakee, WI 53597

Machine Schematic

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Electrical Panel

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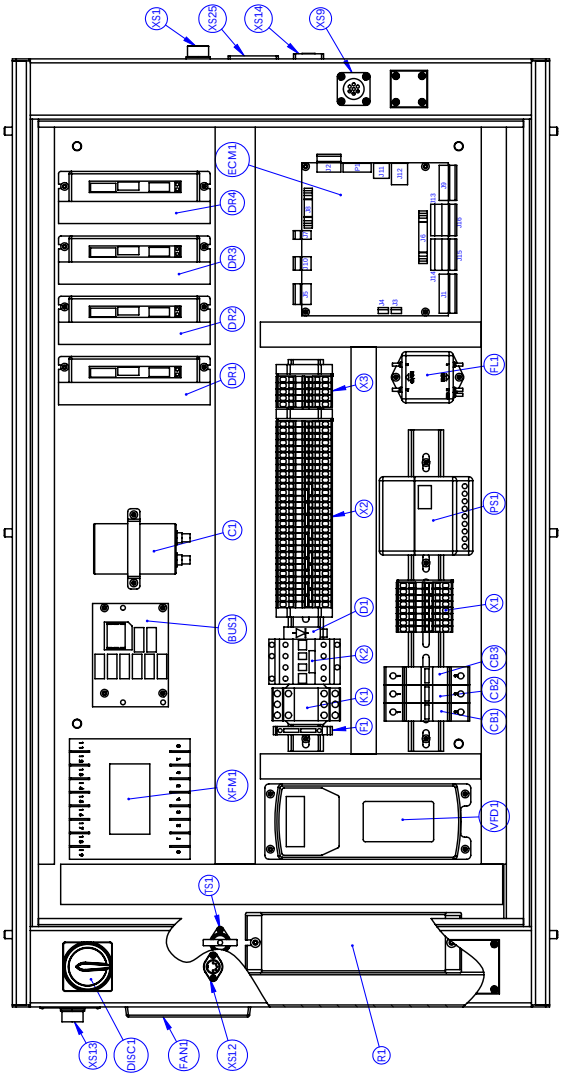
SOLIDWORKS Electrical

14.12 ELECTRICAL CABINET LAYOUT



REF	PN	DESCRIPTION
XS13	37936	CHILLER ALARM CONNECTOR
DISC1	30454	MAIN DISCONNECT
FAN1	37526	CABINET FAN
XS12	30178	ACC. PORT 2
TS1	37420	BRAKE RESISTOR THERMAL SWITCH
R1	37906	BRAKE RESISTOR
VFD1	35717	SPINDLE MOTOR VFD
CB1	37521	MAIN BREAKER
CB2	37521	MACHINE BREAKER
CB3	37522	ACC. BREAKER
X1		X1 TERMINAL STRIP
PS1	37349	24 VDC POWER SUPPLY
FL1	32350	EMI FILTER
ECM1	37506	MACHINE CONTROL BOARD
F1	38924	FUSE HOLDER
	38693	FUSE
K1	37515	DRIVE RELAY
K2	37343	VFD CONTACTOR
D1	37514	FLYBACK PROTECTION DIODE
X2	34127	X2 TERMINAL STRIP
X3	34127	X3 TERMINAL STRIP
XFM1	30459	DRIVE TRANSFORMER
BUS1	32005	DC BUS BOARD
C1	30468	DC BUS CAPACITOR
DR1	32000	X-AXIS DRIVE
DR2	32000	Y-AXIS DRIVE
DR3	32000	Z-AXIS DRIVE
DR4	32793	A-AXIS DRIVE (OPTION)
XS9	30235	4TH AXIS CONNECTOR
XS14	34130	PPC COM PORT
XS25	37351	COMPUTER POWER
XS1	37353	OPERATOR BOX CONNECTOR

14.13 OPERATOR CONSOLE SCHEMATIC