PoKeys57CNCpro4x25 and Mach4

Step by step guide - a.k.a. beginners guide

Version: 1.00

SAFETY INFORMATION

This product is intended for integration by the user into a computer numerical control (CNC) machine. It is the user's responsibility to assess the overall system design and address all safety considerations that affect the users and equipment. The user assumes all responsibility for system design, including compliance with regulatory standards and codes issued by the applicable entities. PoLabs do not make any claims as to the suitability of this equipment for the user's application. Serious personal injury or equipment damage can occur from the improper integration, installation or operation of this product.

This product is not guaranteed to be fail-safe. The system that this equipment is used with shall be fitted with a separate means of fail-safe protection, emergency-stop capability and/or system power removal. This equipment may be connected to dangerous power sources, including electrical power sources. Dangerous voltage levels may be present at this equipment or at connected devices. Measures must be taken to prevent persons from contacting voltage sources which may be present. Equipment should be housed inside an enclosure suitable for the intended environment. Safety interlocks should be provided to prevent any and all dangers to personnel.

CNC machine tools are inherently dangerous, and can cause injury to operators and maintenance personnel. Operators and maintenance personnel shall be properly trained in the safe use, operation and maintenance of such machines. Automated machines that this equipment may be used with can move at any time. All persons exposed to such machines must understand the dangers that are present.

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In this tutorial we will describe a step by step procedure how to build your own electronic system for CNC Machine and use Mach4 software with PoKeys plugin to get your CNC up and running.

This tutorial focuses on the electronic system of the CNC machine with software and leaves out mechanical design. We will assume that the target CNC machine has 3 axes with one motor per axis, however, the major part of this document applies in other cases as well.

Getting familiar with electronic components

For a three-axis CNC machine you will need the following parts:

- 3x stepper motor (one per axis),
- Electronics power supply (e.g. PoPower),
- PoKeys57CNCpro4x25 controller with integrated stepper motor drivers,

Additionally (not necessary, but helpful):

- PoCANPendant 1C with manual pulse generator,
- PoNETkbd48CNC keyboard with 48 keys, designed for CNC operation,
- Limit switches and E-Stop button.

Stepper motors

The motors vary in rated current and holding torque. As you can find out, not all stepper motors have the same number of wires. The 4-wire stepper motor has 1 coil per phase and 8-wire has 2 coils per phase and can be run in parallel or serial mode. Parallel mode needs higher current, has lower inductance and better torque. Serial mode needs lower current and has lower torque. You can find a more detailed explanation about stepper motors here (http://blog.poscope.com/stepper-motor-driver-user-manual-complete-edition/internet).
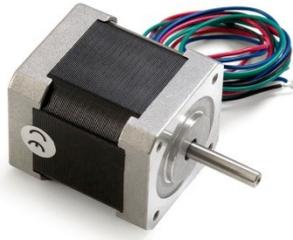
Nema 17 (SY42STH47-1684B Stepper Motor)
4-wire

Nema 23 (SY60STH86-3008 Stepper Motor)
8-wire

PoPower24-100

PoKeys57CNCpro4x25 requires external 22-26 V power supply to be connected to the board in order for the device to operate correctly. Choose appropriate power supply, taking into account witch stepper motor and which current setting you are going to use. It is recommended to use at least 100w power supply, so PoPower24-100 could be used.

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PoKeys57CNCpro4x25 controller

PoKeys57CNCpro4x25 is a blend between general purpose PoKeys device and motor controller as well as stepper motor driver. The device is targeted primarily for controlling up to 4 stepper motors in various applications with the addition of powerful PoKeys device features. Device contains dedicated connectors for connections with limit switches, CAN peripheral devices, spindle and VFD signals, plasma connection etc. In addition, 10 V analog inputs with 12-bit resolution are available.
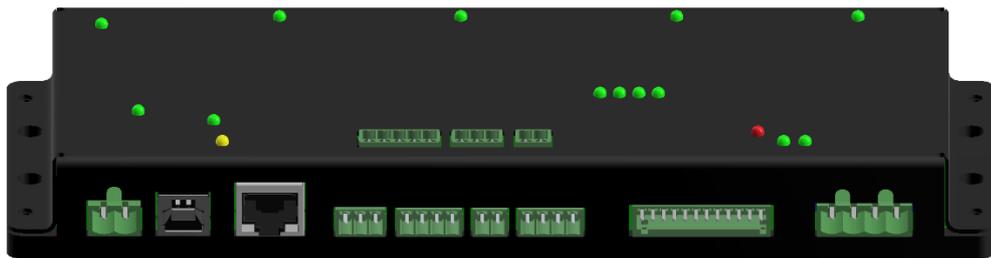
Let's start connecting

Power supply

- Start connecting power supply part, but don't plug it into the AC socket until all connections are done.
- You should consider some general rules. Use color coded cable to connect all three AC plug wires (L, N and PE). L-brown, N-blue, PE- yellow/green. In some countries colors can be different as described. Remember - the yellow/green wire must be always and exclusively used for PE wire (Protective Earth)!
- Keep the AC plug disconnected until you wired everything and double checked the wiring.
- Remove approx. 1 cm (1/3 inch) of insulation at wire end. Insert wire's end into power supply connector and use a screwdriver to attach it. It is recommended to use proper crimp connector at the end of the cables if possible to protect the wire or at least a ferrule.
- Use red and black (blue) wires for DC voltage. Red for positive power supply lines (+V/+24V) and black for negative power supply lines (-V, GND).
- Connect DC outputs (+V, -V) from the PoPower24-100 to PoKeys57CNCpro4x25 power supply connector. Use screwdriver to attach.

Stepper motors

Connect the stepper motor wires to the stepper motor driver outputs on PoKeys57CNCpro4x25; marked on the enclosure. Use a table below for 4 or 8-wire stepper motor.

4-wire stepper motor pin-out:

green	black	blue	red
pin **A**	pin **A'**	pin **B**	pin **B'**

8-wire stepper motor pin-out (parallel coil connection):

yellow/white	yellow	red/white	red	green/white	green	black/white	black
pin **A**	pin **A'**	pin **A'**	pin **A**	pin **B**	pin **B'**	pin **B'**	pin **B**

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Connect limit and home switches

We will take a look on how to connect limit and home switches of your CNC machine to the PoKeys57CNCpro4x25 controller.

The controller has screw terminals Limit for one switch per each axis (each motor output). The limit switch terminals have 24V output voltage for power supply to the limit switch in case it is needed. If you are using our PoHome1IRNPN homing sensor, please use NPN sensor type and connect it to the terminals with power supply and sensor input on the right pins.
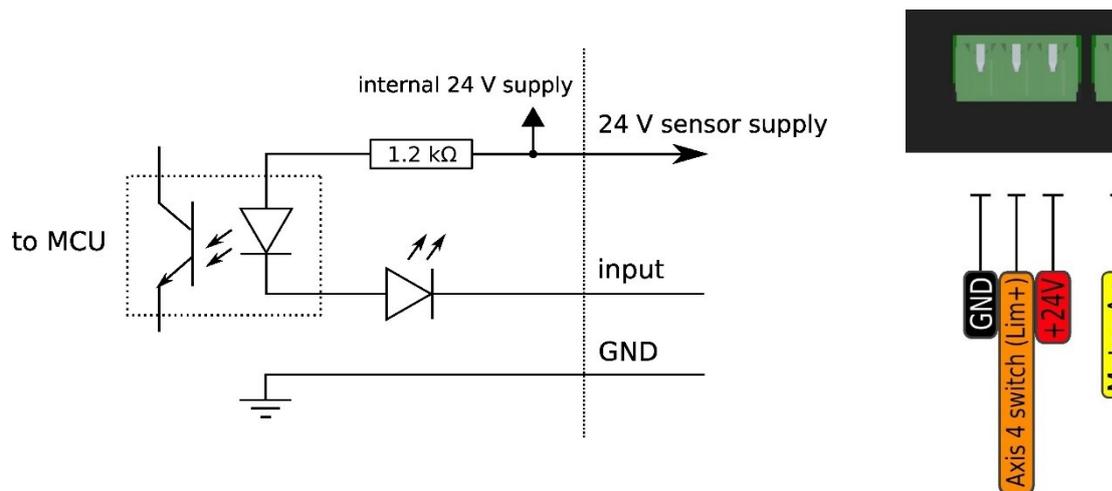
Up to four switches can be connected to the controller.

Mechanical switches

Mechanical switches can be directly connected between the GND and the selected input terminal. Both NC (normally-closed) and NO (normally-open) switches are supported.

If NO (normally-open) switches are used, select the 'Invert' option for the selected switch in the Pulse engine configuration in PoKeys plugin for Mach4.

If no switch is connected to specific input, make sure that it is configured as 'Disabled' in the Pulse engine configuration in PoKeys plugin in Mach4.

Electronic switches with pure NPN (open-collector) output

There are various types of electronic switches (e.g. inductive, capacitive, optical switches etc.) with a pure NPN (open-collector) type output. These can directly be connected to PoKeys57CNCpro4x25 inputs, as shown on the illustration below.

Connect the GND of the sensor to GND of the PoKeys57CNCpro4x25 GND. Connect the sensor's signal output to PoKeys57CNCpro4x25 input (IN) terminal. Connect sensor's positive power supply to the 24 V positive terminal of the PoKeys57CNCpro4x25. Switches/sensors with pure NPN-type outputs have no built-in pull-up resistors.

Electronic switches with PNP output

PoKeys57CNCpro4x25 is not designed to be used with switches or sensors with PNP-type output.

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Connect probe

Probe input is available on the same side as the axis limit switches and motor connectors and has the same characteristics as limit switches connectors.

Connect E-stop switch

PoKeys57CNCpro4x25 is designed to include an emergency switch on the board – hence the dedicated connector for the emergency switch. The e-stop connector is wired in the same way as limit switches, without the 24V power supply. The mechanical switch is connected between ES (e-stop) and G (GND) terminal. For safety reasons, NC type switch and connection is recommended.

Connecting other signals with the PoKeys57CNCpro4x25 device

Check the specifications of your external device to determine the type of the input or output signals. There is also more in-depth explanation of other connections in the PoKeys57CNCpro4x25 manual.

External device logical inputs (e.g. low current CMOS or TTL logical levels)

Compatible PoKeys signals: Any pin marked as 'Pin x' (where x is a number) that can be configured as digital output (DO5 or DO5_D types)

Wiring: Connect PoKeys GND to common ground of the external device, connect PoKeys output pin to external device input

External device logical outputs (e.g. CMOS or TTL logical level output signals)

Compatible PoKeys signals: Any pin marked as 'Pin x' (where x is a number) that can be configured as digital input (DI33 types)

Wiring: Connect PoKeys GND to common ground of the external device, connect PoKeys input pin to external device output

External device optocoupler inputs - active high

Compatible PoKeys signals: PoKeys pin marked as either of DO5, DO5_D, OCOC or REL type in PoKeys57CNC specifications - **suggestion: use OCOC or REL**

Wiring for DO5, DO5_D:

Connect PoKeys GND to common ground of the external device (or a dedicated input ground connection if applicable), connect PoKeys output pin to external device input

Wiring for OCOC:

Connect PoKeys OC+ to positive power supply voltage (max. 50 V), OC- to external device input and negative power supply to external device common ground (or a dedicated input ground connection if applicable)

Wiring for REL:

Connect one PoKeys relay contact to positive power supply voltage, the other relay contact to the external device input and negative power supply voltage to external device common ground (or a dedicated input ground connection if applicable)

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External device optocoupler inputs - active low

Compatible PoKeys signals: PoKeys pin marked as either of DO5, DO5_D, OCOC or REL type in PoKeys57CNC specifications - **suggestion: use OCOC or REL**

Wiring for DO5, DO5_D:

Connect PoKeys GND to common ground of the external device, connect PoKeys pin to external device input.

Wiring for OCOC:

Connect OC+ to external device input and connect OC- to external device common ground (or a dedicated input ground connection if applicable). If external device input requires a power supply input, connect the appropriate power supply (do not use +5V from the PoKeys device or the power supply used for powering the PoKeys device to avoid ground loops).

Wiring for REL:

Connect one PoKeys relay contact to external device input and the other relay contact to the common ground of the external device (or a dedicated input ground connection if applicable)

External device optocoupler outputs (also relay outputs) - both optocoupler pins are accessible

Compatible PoKeys signals: Any pin marked as 'Pin x' (where x is a number) that can be configured as digital input (DI33 types)

Wiring: Connect PoKeys GND to negative lead of the external device output (sometimes marked as common), connect PoKeys input pin to external device positive output lead

External device optocoupler outputs - active low (signal is tied to ground by the external device when active)

Compatible PoKeys signals: Any pin marked as 'Pin x' (where x is a number) that can be configured as digital input (DI33 types)

Wiring: Connect PoKeys GND to common ground of the external device, connect PoKeys input pin to external device output

External device optocoupler outputs - active high (signal is tied to positive power supply by the external device when active)

Compatible PoKeys signals: PoKeys pins are not compatible with this signal type

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Connecting spindle controller

There are different possibilities to control the spindle motor, depending on the spindle controller control inputs available and their types. The following inputs are commonly found on spindle motor controllers:

- master on/off input: turns the spindle motor on or off
- forward direction: activates the forward direction (and usually also starts the motor)
- backwards direction: activates the backwards direction (and usually also starts the motor)
- spindle speed voltage input: usually indicated with the variable resistor (potentiometer) and referenced to a certain common voltage (also one of the supply leads for the indicated potentiometer)

⚠	The selected PoKeys output signal can be found in the Mach4 output signals list as described in chapter *Mapping PoKeys digital IO signals to Mach4 IO* on page 16

⚠	Pay attention when connecting galvanically isolated I/O pins of the PoKeys device - these pins have a dedicated ground signal named GNDi. Do not connect GNDi to GND since this renders the galvanic isolation irrelevant.

Spindle controller with master on/off function or with forward direction signal only

If your spindle controller only has an on/off control input and the spindle speed is either constant or manually adjusted, use the appropriate PoKeys pin to drive the spindle controller on/off control input (check chapter *Connecting other signals with the PoKeys57CNCpro4x25 device* on page 9 for more information).

Configure the selected output pin of the PoKeys device in Mach4 output signals configuration (Config > Mach4 > Output signals) for 'Spindle On' or 'Spindle Fwd' signal.

Spindle controller with on/off, forwards and backwards direction signals

If your spindle controller has on/off, forwards and backwards control inputs and the spindle speed is either constant or manually adjusted, use the appropriate PoKeys pin to drive the spindle controller control inputs (check chapter *Connecting other signals with the PoKeys57CNCpro4x25 device* on page 9 for more information).

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Configure the selected output pins of the PoKeys device in Mach4 output signals configuration (Config > Mach4 > Output signals) for 'Spindle On', 'Spindle Fwd' and 'Spindle Rev' signals.
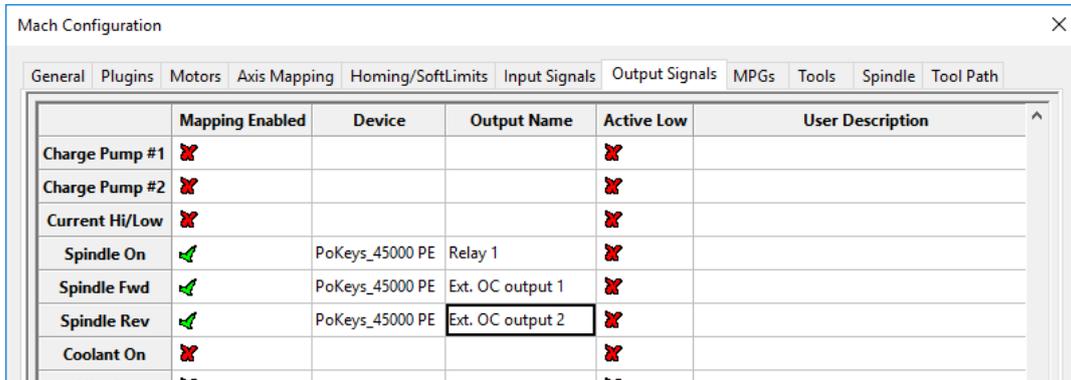
Spindle controller with analog spindle speed input

First, connect other spindle controller digital control signals as described above for on/off and direction control signals.

Use the 0-10V analog output signal of the PoKeys device to control the speed of the spindle. Connect GNDi (pay attention to using GNDi and not GND) to the common or ground voltage signal of the spindle speed input. Connect 0-10V analog output signal of the PoKeys device to control voltage signal of the spindle speed input. +10V voltage output of the spindle controller (VFD) should be left unconnected. Make sure that the spindle controller is configured to accept 0-10V analog voltage signal as the spindle speed reference.

The 0-10V analog output signal of the PoKeys device is generated by low-pass filtering the PWM signal (on pin 17 in case of PoKeys57CNCpro4x25). Therefore, the signal is configured in PoKeys plugin for Mach4 under the 'Miscellaneous' tab. Set the PWM frequency to 20000 Hz, enable PWM on pin 17, select Pin 17 as the 'Spindle output' and check 'Set to 0 when OFF', as shown on image below.
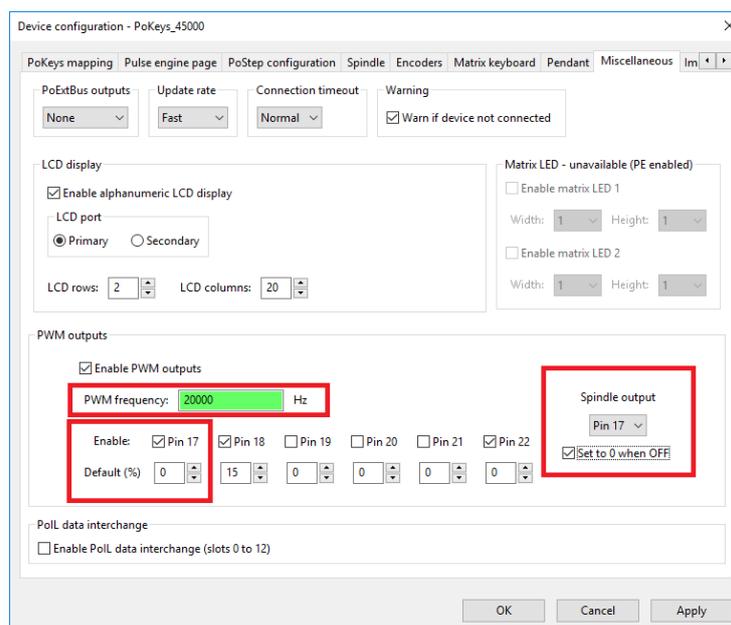
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Connecting spindle speed sensor

PoKeys57CNCpro4x25 expects that the spindle speed sensor outputs a digital signal with one (index) pulse per spindle rotation. Connect the spindle speed signal to PoKeys pin 13 (pin 5 of the Encoders connector – Index pin) and the sensor ground to PoKeys ground.

The spindle speed measurement uses PoKeys's 'Ultra-fast encoder' input. Check that 'Enable 'ultra-fast' encoder' option is enabled under 'Encoders' tab.
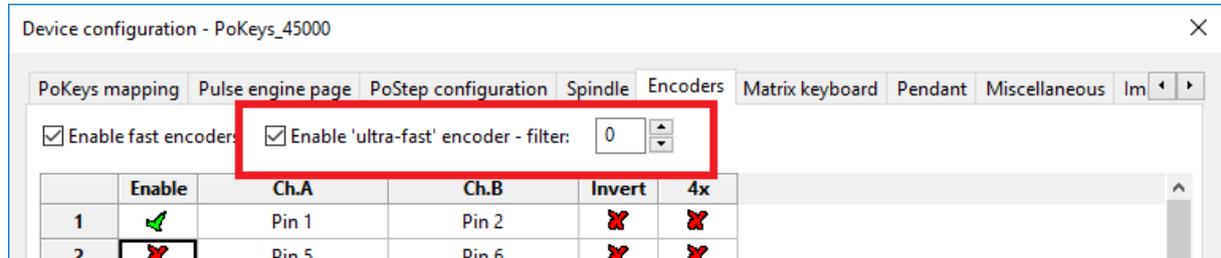
Configure the spindle speed measurement in the PoKeys plugin configuration dialog under 'Spindle' tab to use 'Index (mill)' or 'Index (lathe)', as shown below. The lathe option expects a lower frequency signal and uses different filter settings.
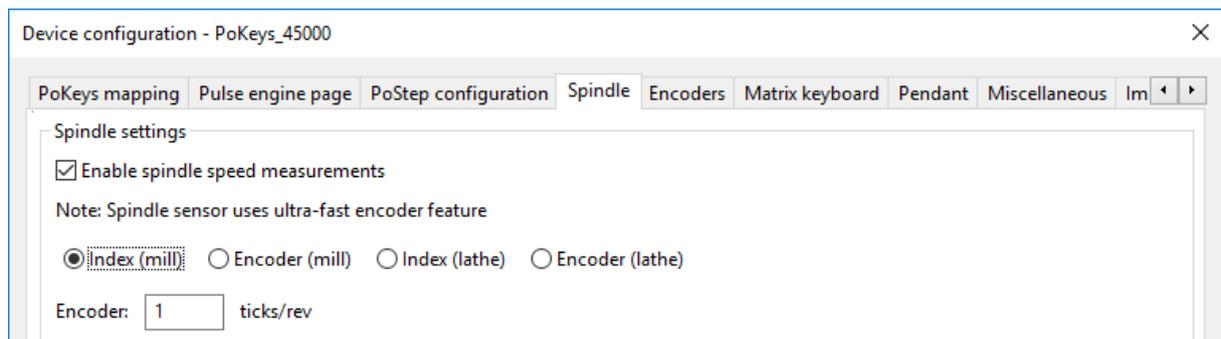
Connecting spindle encoder

PoKeys57CNCpro4x25 expects that the spindle encoder outputs a digital signal and an index pulse. Connect the encoder signals to the appropriate pins of the 'Encoders' connector on the PoKeys57CNCpro4x25 device.

The spindle speed measurement uses PoKeys's 'Ultra-fast encoder' input. Check that 'Enable 'ultra-fast' encoder' option is enabled under 'Encoders' tab.
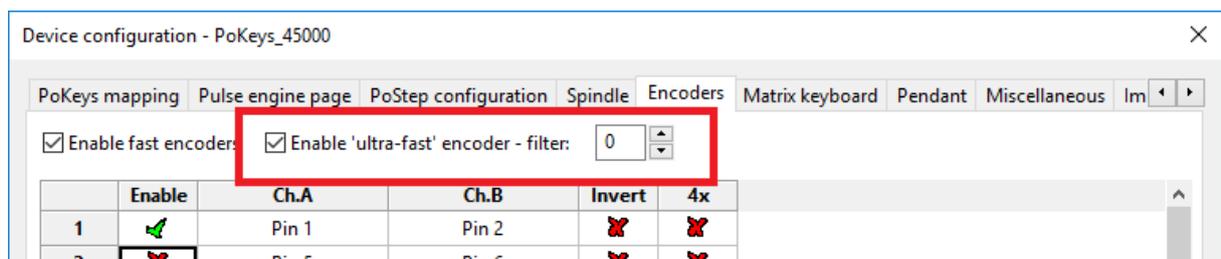
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Configure the spindle speed measurement in the PoKeys plugin configuration dialog under 'Spindle' tab, as shown below. The lathe option expects a lower frequency signal and uses different filter settings. Enter the encoder resolution (in encoder ticks per revolution) in the field 'Encoder'.
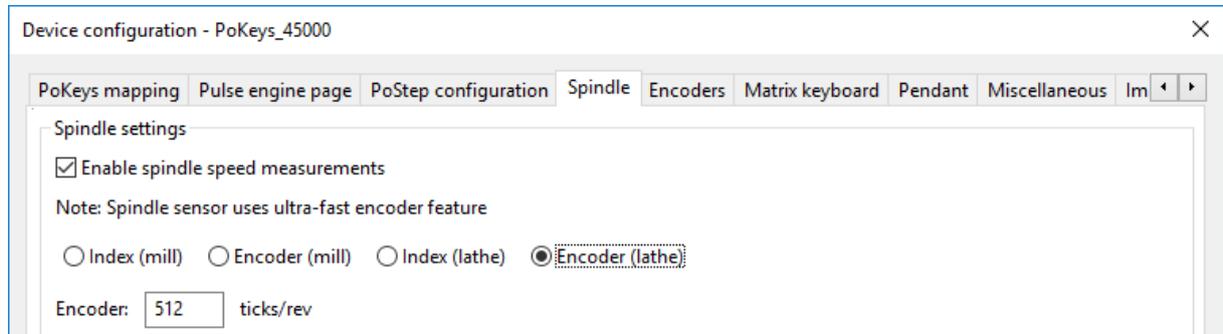
Enabling threading support

PoKeys57CNCpro4x25 supports threading operation with either index-only or encoder+index signals. Select 'Enable threading support' in the 'Spindle' tab of the PoKeys plugin configuration. Note that only lathe signal types for the spindle speed sensor can be selected.

It is suggested to leave the gain settings unchanged.
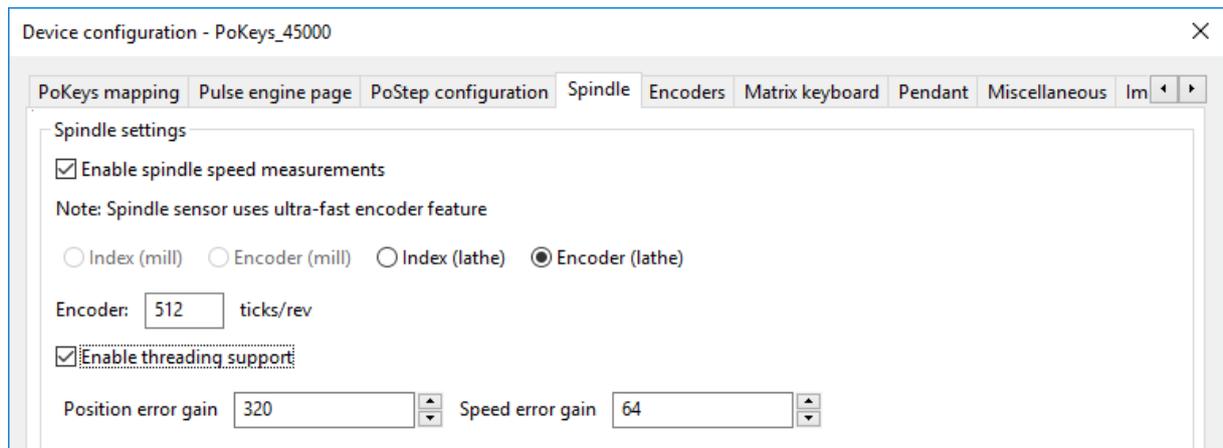
Connect other peripherals

If you are going to use Pendant and/or Keyboard, connect it to CAN connector on PoKeys57CNCpro4x25 board. Make sure, that pendant has CAN enabled.

Final check and power up

After connecting all together, make some final check before plugging power supply cable into AC socket.

⚠	Make sure to separate high-voltage / high-current and low-voltage signals wires to avoid unnecessary noise injection into the signal wires.

Finally, we connect entire CNC electronic-control system. Three stepper motors for axis X, Y and Z with associated step drivers, controller and power supply.

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Mapping PoKeys digital IO signals to Mach4 IO

PoKeys pins can be mapped to Mach4 digital input and output signals via the Config > Mach4 > Input signals or Outputs signals menu/configuration dialog.

The signals are organized in multiple Mach4 Devices, as described in the table below (xxxx indicates a serial number of the PoKeys device)

PoKeys device in the Mach4 devices list	Accessible signals
PoKeys_xxxx	Regular "PoKeys" pins (pins marked as 'Pin x' in the device pinout)
PoKeys_xxxx PoExtBus	PoExtBus outputs
PoKeys_xxxx PE	Pulse engine related signals: - dedicated home and limit switch inputs - home and limit switch statuses[1] - External inputs (not used in PoKeys57CNC) - Motor driver error inputs - OC (optocoupled open-collector) outputs - Relay and SSR relay outputs

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[1] Home and limit switch status signals report the aggregated and actual status of detected home and limit switches as calculated by the device (based on the configuration of the device). These are not physical signals direclty and should not be used when configuring home and limit input signals in Mach4!

Basic configuration of the PoKeys57CNCpro4x25 device

Before we start with the CNC software, let's take a look on how to update the firmware of the PoKeys controller to the latest version and configure the main device settings. Download latest version of *PoKeys software (configuration tool)* and install the setup package on your computer.

Selecting PoKeys57CNCpro4x25 connection type

PoKeys57CNCpro4x25 supports both USB and Ethernet connections and allows the user to choose the preferred connection type. The following facts can help choosing the connection type when in doubt which one to use:

- **Cable length**: USB devices are limited to a combined cable length of 5 meters, while Ethernet cables are limited to 100 meters in length

- **Power supply**: both connection types require that the PoKeys57CNCpro4x25 device is connected to an external power supply.

- **Reliability**: both connection types provide high reliability and protection against electrical noise. However, since Ethernet devices are galvanically isolated, the odds of **ground loops** are greatly reduced

- **Convenience**: since most of computers have built-in USB ports, connecting the PoKeys57CNCpro4x25 to a PC via a USB cable is the most convenient solution. However, this requires that the computer is in close proximity to the machine. On the other hand, Ethernet cable can be connected to a standard router and make the PoKeys57CNCpro4x25 device available to any PC in the network

- Ethernet only feature: PoKeys57CNCpro4x25 device feature a built-in **web interface** and support for **Modbus TCP** (Server). Both are accessible to other devices in the network, allowing a remote supervision of sensor values or other parameters

Using USB connection

Step 1: Locate a free USB 2.0 port on your computer (1) and PoKeys57CNCpro4x25 board (2) and connect them with a standard USB cable.

Step 2: Connect the PoKeys57CNCpro4x25 board to an appropriate power supply (3).

Step 3: Install PoKeys software

Step 4: Open PoKeys application, follow the instructions to update the firmware, then connect to your PoKeys57CNCpro4x25 device and enable Fast USB interface (go to Device > USB > Enable Fast USB interface).
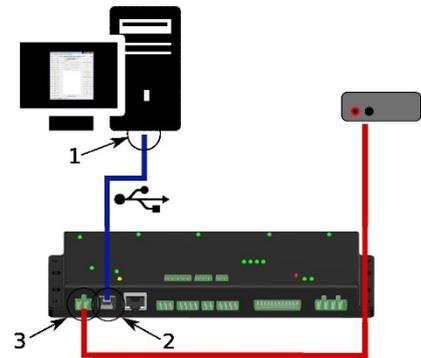
Step 5: Remove the USB cable from PoKeys57CNCpro4x25 device, turn off the power to the PoKeys57CNCpro4x25 device, then re-apply the power and insert the USB cable again. The computer will find a new device and search for drivers. See FAQ section of the manual if driver installation fails.

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Using Ethernet connection

Ethernet connection can be used to connect PoKeys57CNC and PC directly or via router. Accessing the PoKeys57CNC device over a wireless network (employing a wireless router) is highly discouraged.

Since most network devices use IP-based communication, a proper configuration of a network is of utmost significance. Each device in the network must have a unique IP address assigned – this has to be done manually (if using direct connection to a PC) or is done by a router with a DHCP server. PoKeys57CNC devices are designed to operate in /24 subnets (network mask of 255.255.255.0). Other network configurations can also be used, but the operation of the devices will not be optimal (reduced capabilities of automatic device discovery).

Direct ethernet connection PoKeys57CNCpro4x25 – PC

Make sure that an appropriate IP address is assigned to a network card of your PC, that the PoKeys57CNCpro4x25 device is connected to. Follow the steps, described in the following guide: Change TCP/IP settings in Windows 7.

Step 1: Locate ethernet ports on your router (1) and PoKeys57CNC board (2) and connect them with RJ-45 cable (standard network cable).

Step 2: Connect the PoKeys57CNC board to an appropriate power supply (3).

Step 3: Install PoKeys software

Step 4: see below for configuration of network settings

Step 5: update the device's firmware.
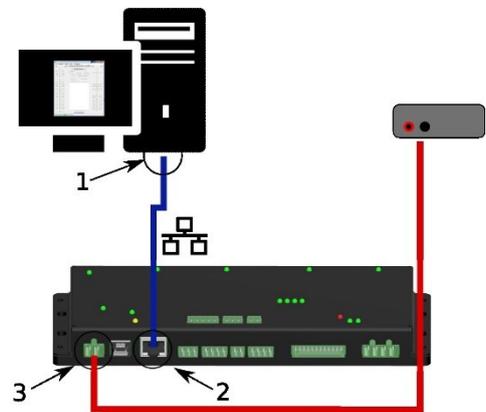
PoKeys57CNCpro4x25 connected to a network with DHCP server

If your router is properly configured, it will automatically assign addresses to your PC and PoKeys57CNC device.

Step 1: Locate ethernet ports on your router (1) and PoKeys57CNC board (2) and connect them with RJ-45 cable (standard network cable).

Step 2: Connect the PoKeys57CNC board to an appropriate power supply (3).

Step 3: Install PoKeys software

Step 4: see below for configuration of network settings
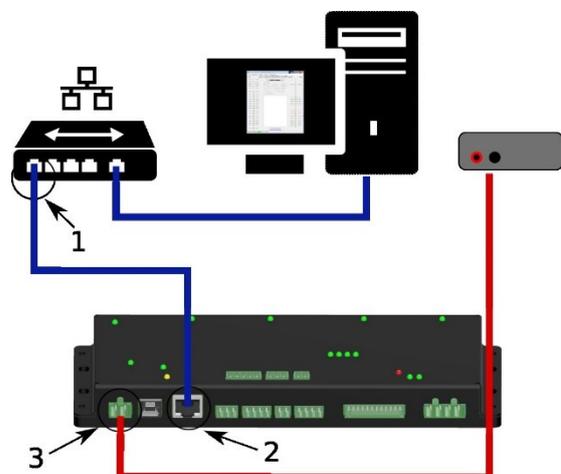
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Step 5: update the device's firmware.

Configuring PoKeys57CNCpro4x25 network settings

Open PoKeys configuration application. A 'Select device' (Connect) dialog will appear, listing all available PoKeys devices that have been automatically detected. The following screen capture shows a list of 4 devices that have been detected – one PoKeys57U device, one PoKeys57E device and two PoKeys57CNCpro4x25 devices. By clicking on the PoKeys57CNCpro4x25 device entry, the device data section on the right of the dialog will show device details, including currently assigned IP address.
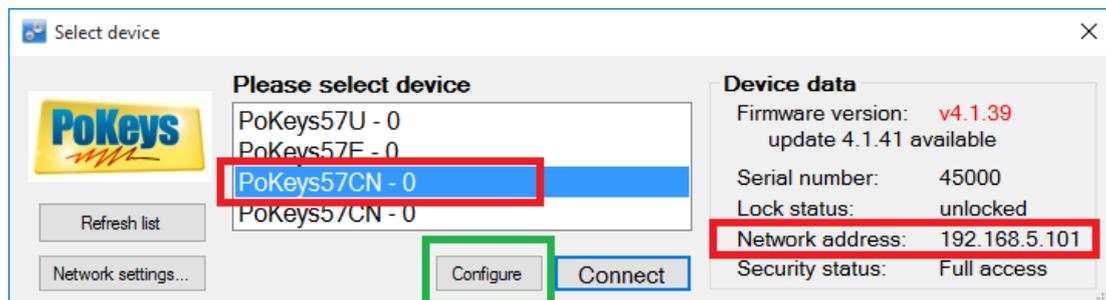
In order to configure the PoKeys57CNCpro4x25 device network settings, click on 'Configure' button and the following dialog will appear, allowing you to change between automatic IP retrieval (using DHCP) or manual configuration.
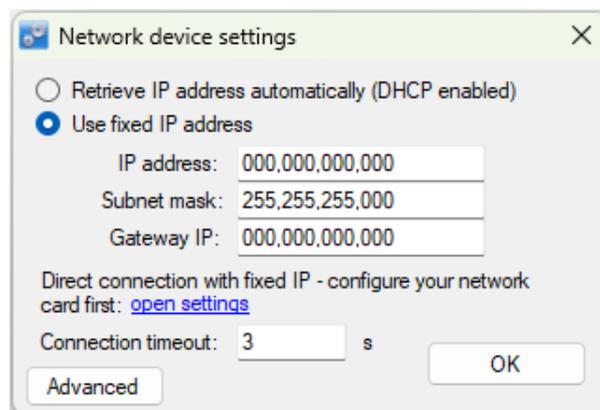
Only IP address can be manually configured here since you are not yet connected to the device fully. In order to configure all network settings, connect to the device first, then open Device > Network device settings.

Autoconfiguration of the device address

PoKeys57CNCpro4x25 devices employ an autoconfiguration process that in case of unconfigured (or misconfigured) PoKeys57CNCpro4x25 device network settings, assigns a temporary address to the device so that the device can be detected by the PoKeys application and configuration updated. **Such address is recognized by the last part of the IP address being equal to .250. This address must not be used during normal operation of the device.**

The autoconfiguration can be disabled in network device settings dialog under 'Advanced' options (by checking the 'Disable automatic cross-subnet detection' option). If automatic device discovery option is disabled, the software will not be able to automatically detect PoKeys devices in the network and a correct IP address of the device will be needed to connect to it. If settings are misconfigured, the device can be put into Recovery mode and settings reset, as described in the PoKeys manual.

Now, we can start with software setup.

Mach4 setup

To control your CNC Machine you need a program that can translate the G-code to machine motion. We will use Mach4 for this demonstration.

1. Download Mach4 and install it on your computer.
2. Download Mach4 PoKeys plugin (the latest version is available on PoLabs homepage under Downloads). Copy both plugin files and place them inside "Plugins" folder which is found inside Mach4 installation folder.
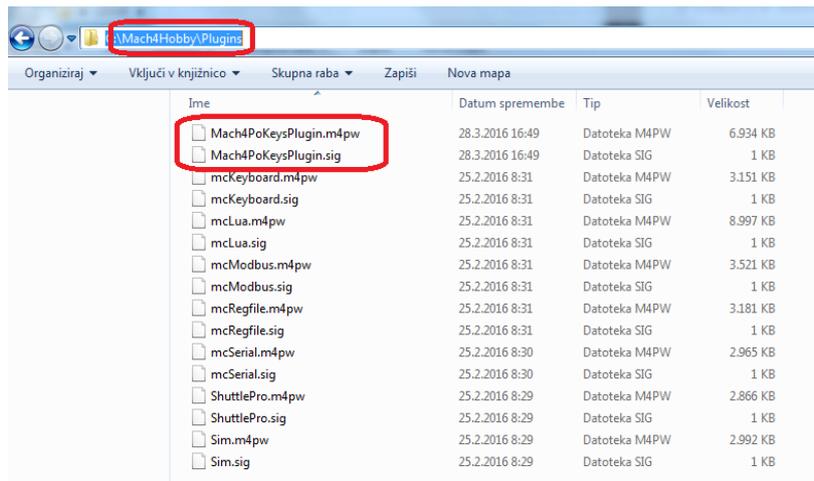
3. Connect PoKeys57CNCpro4x25 using USB or Ethernet cable to computer and run Mach4 software.
When Mach4 opens, a welcome screen from the PoKeys plugin should appear. Click on "Open Add new device wizard" to start the configuration. The configuration wizard is straight forward and it shouldn't be a problem to follow it.

4. Select your Pokeys device and click *Next*.
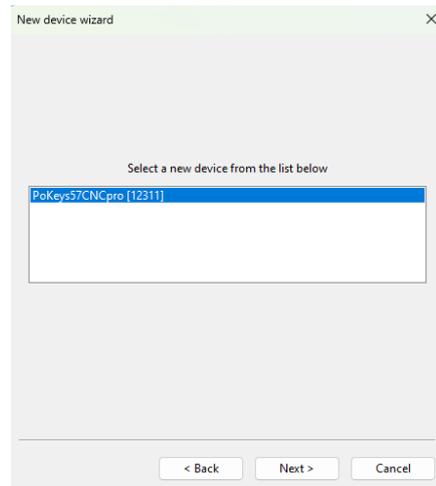
5. In *Pulse engine options* Motor drivers are already selected, under *Peripheral options* PoPendant and/or PlasmaSensDiv can be selected, if you are using one. You can also rename your device if you want.
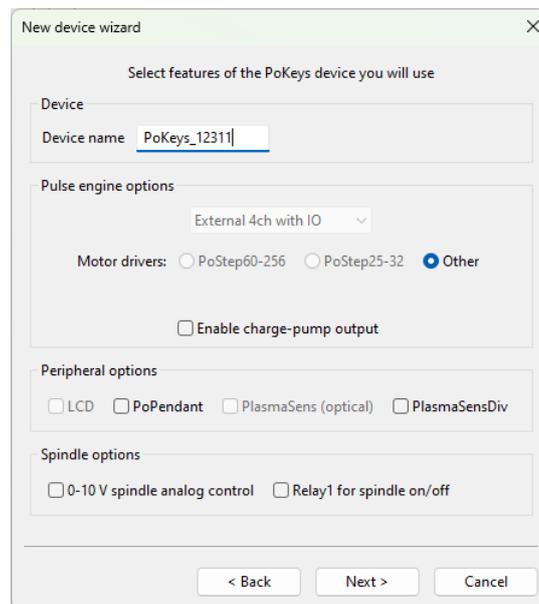
6. On the next page of the wizard, you can select the configuration of switches on your machine. If you are not certain on which option suits your machine best, use the 'Detect switches and buttons' wizard by clicking the button on the top of the dialog. This will guide you through the switches setup.
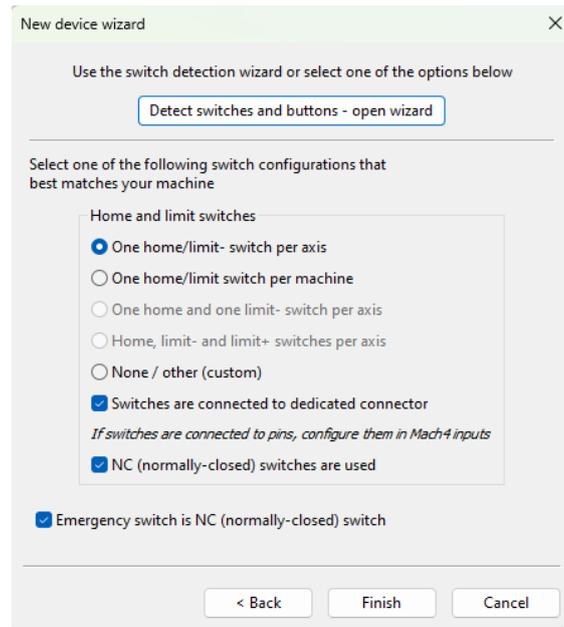
7. Please restart Mach4 software. When Mach4 starts, '*E-Stop condition!*' or '*E-stop due to limit switch!*' text may appear in status list in the lower left corner of Mach4 window. This can happen due to the following causes:

   o E-Stop switch is pressed: to enable Mach4, release the E-stop switch

   o Polarity of E-stop switch is not configured correctly – make sure that 'Invert emergency switch input' option is selected if E-stop switch with NO (normally-open) contacts Is used

   o Limit switch is active: the machine activated the limit switch – use limit override option

   o Polarity of limit switch is not configured correctly – make sure that 'Invert' option for the selected limit switch is selected in NO switches are used

   o Limit switch is not connected, but is configured: check that unused switches are configured with option 'Disabled' in Pulse engine configuration in the PoKeys plugin configuration.
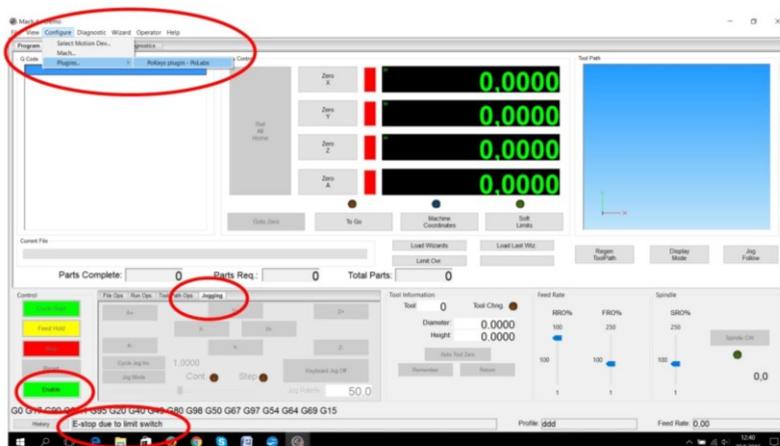
8. It is recommended to restart Mach4 after making major changes in plugin (changing device, adding new device, changing Pulse engine type etc).

9. Configure the Mach4 with the correct settings for your machine and motors – open Configure > Mach4 menu and switch to 'Axis mapping' tab. Check that the PoKeys57CNCpro4x25 motor outputs (Motor0...Motor3 correspond to MOTOR1...MOTOR4 connectors on the PoKeys57CNCpro4x25 device) are correctly assigned to each axis.

    Next, switch to 'Motors' tab and select Motor0 in the list on the right. Enter the correct 'Counts per unit', maximum velocity and acceleration that suit your machine configuration. Here you can also find 'Reverse' option that will reverse the direction of motor travel if you later discover that the motor runs in the wrong direction. Once complete, click OK.

10. Now everything is set up for Jogging or running G-code.

    - Click on Enable button.
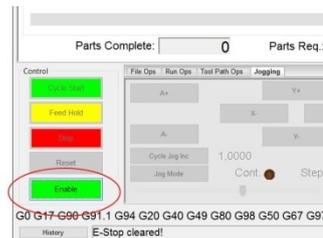
    - Option 1: select *Jogging* tab and use axis **+** and **−** buttons to drive motors
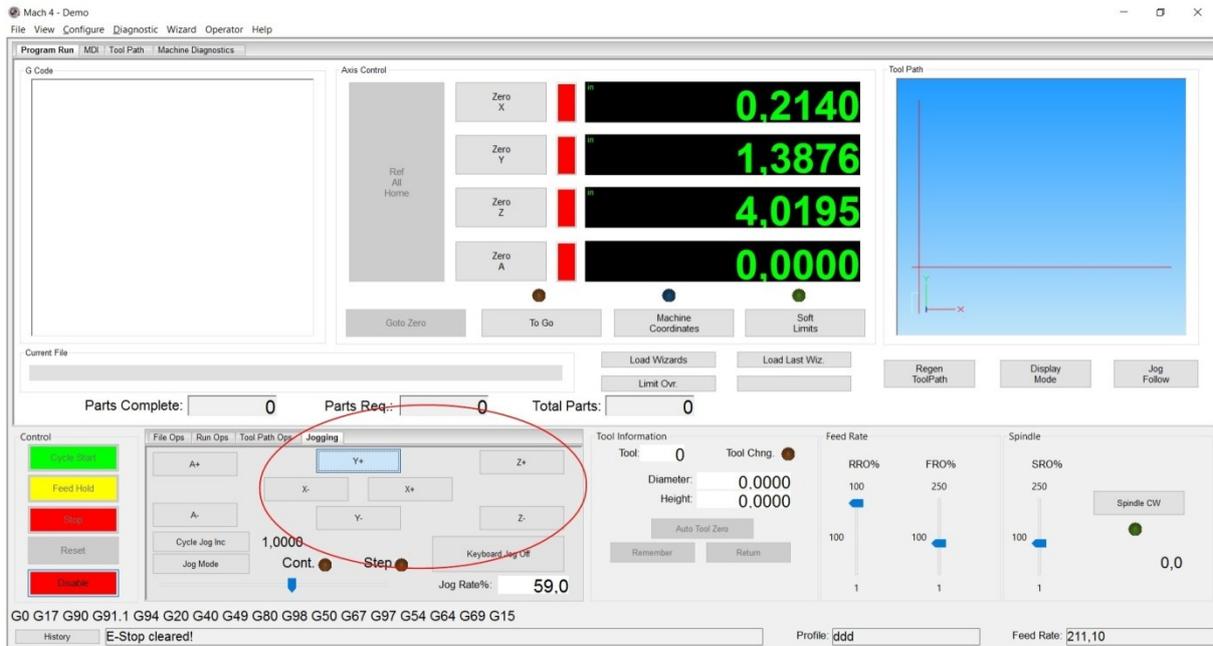
- Option 2: select *FileOps* tab, click on Load G Code button and select *roadrunner.tap* from *Mach4Hobby\GcodeFiles* folder and then press *Cycle Start* button.
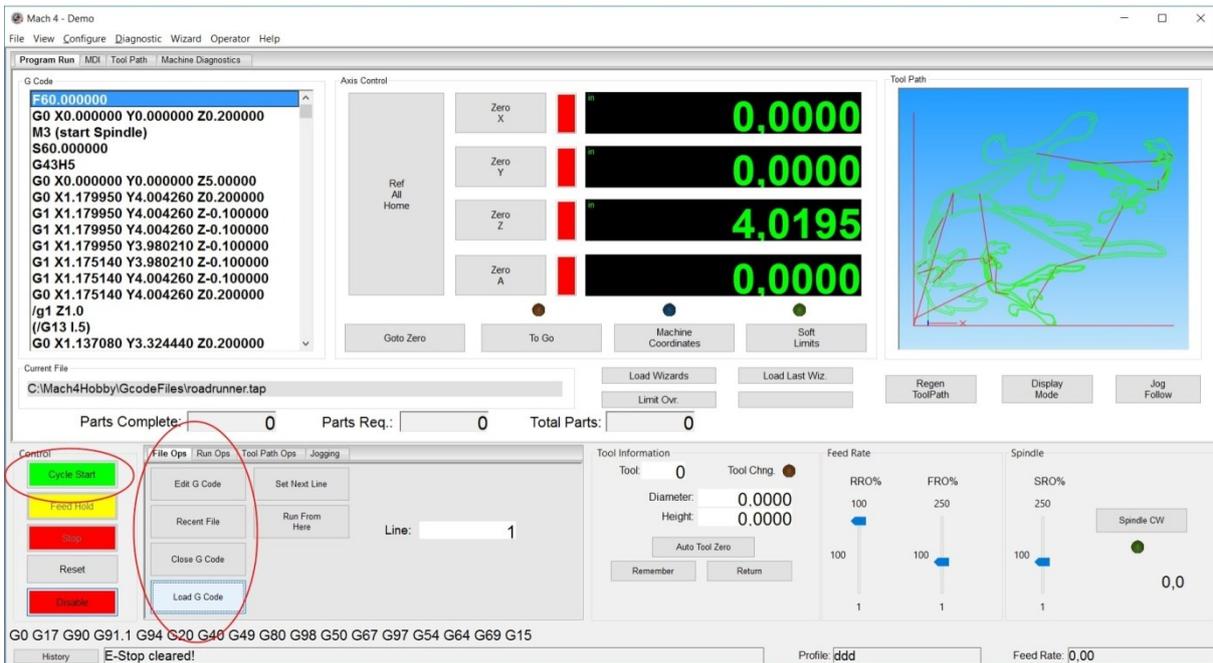
Open user manual "PoKeys plugin for Mach4" that is provided with the Mach4 plugin for description of other available settings for the PoKeys device in Mach4.

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