

USB motion card

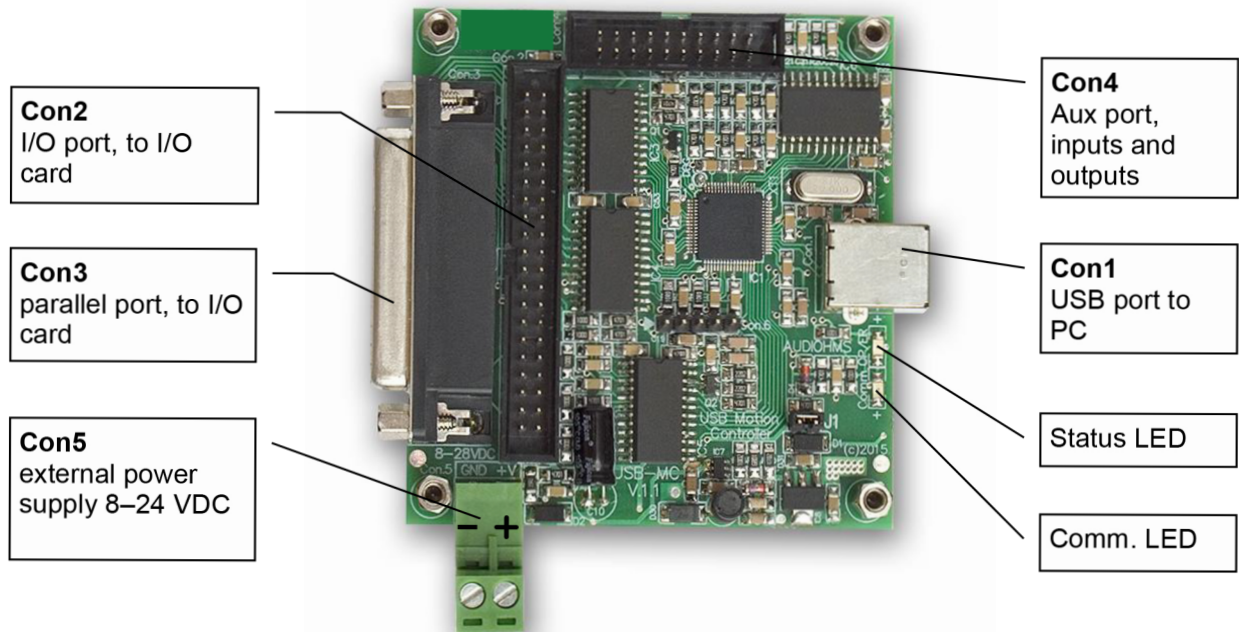


Figure 1 USB motion card

Description

USB motion card is motion controller designed for use with popular Mach3 CNC control software in Windows XP, Vista, 7, 8, 8.1 and 10 operating systems with 32-bit (x86) and 64-bit (x64) architectures. As external controller, it brings various improvements in comparison to using Mach3 software over parallel port. USB motion card does not require installation of Mach3 LPT driver.

USB motion card takes over all real-time tasks that require precision timing. Thus, computer CPU is less loaded, so that Mach3 now can work on less powerful desktop, laptop, and even tablet computers. Considering that controlling task does not need high performance computer, the price for complete control system can now be considerably reduced.

At the same time, much higher output frequency for step signal (up to 250 kHz) is achieved and much better quality of output than it is possible with parallel port regardless of performances of used computer.

The parallel port is becoming less and less common and is almost obsolete. Newer computers often do not offer this port. USB motion card is using USB for communication and USB port is present on all modern systems.

A large number of functions have been added and existing are improved. PWM output can have much higher frequency and higher resolution, PWM power compensation in relation with feedrate is added, implemented hardware MPG mode, more detailed debouncing adjustments for all input signals, and much more.

USB motion card has 16 digital outputs and 14 digital inputs in comparison to 12 digital outputs and 5 digital inputs that are available from parallel port. In addition, USB motion card has analog input which is not possible to realize via parallel port.

All digital inputs on USB motion card are realized with Schmitt trigger digital input circuits, thereby significantly reducing the susceptibility to noise and interference.

In order to achieve compatibility with existing systems which use input/output cards (breakout boards), USB-MC has 25-pin LPT connector built-in. That means that USB motion card can be used easily with existing systems which use parallel port.

Additional inputs and outputs are available via appropriate connectors, and via add-on input/output boards that can be easily connected to USB motion card.

Mach3 plugin contains integrated latest compatible version of firmware so in case that firmware has to be updated, this process is automatic and easy for user.

For connection of USB motion card with PC, it is important to use high quality cable, as short as possible, preferably not longer than 1.5m.

NOTE: USB motion card is powered from USB port so in its primary function external power supply is not necessary. However, external power supply is required if input/output add-on Advanced breakout for usb motion card is used because this card requires higher voltage than 5V that is available from USB port.

Supported Mach3 functions

- all jogging modes
- spindle PWM out, adjustable frequency 10 Hz – 200 kHz
- spindle index input, adjustable divider
- spindle step/dir axis
- spindle relays (M3, M4 and M5)
- coolant relays (M7, M8 and M9)
- ESTOP input
- MPG (encoder) inputs, all Mach3 MPG modes + hardware mode
- freely assignable functions to any of inputs and outputs
- adjustable active signal state (low/high) for all inputs and outputs
- homing/referencing (single axis and multiaxis)
- hardware limit switches
- softlimits with deceleration for smooth stop
- limits override, auto/manual/external
- charge pump outputs, adjustable frequency (12.5 kHz and 5 kHz)
- slave axes
- probing function (G31)
- laser M10p1/M11p1, e5p1/e5p0 fast outputs (#1-6)
- laser PWM, power compensation (PWM duty cycle can change in relation to velocity of movement), adjustable arbitrary relation curve
- laser PWM, gate by M10/M11
- laser gray scale (8-bit) engraving - **NEW**
- shuttle mode, adjustable acceleration time
- detailed adjustment for debouncing of all input signals
- FRO, SRO or any DRO/Variable control using potentiometer or rotary encoder
- offline mode
- threading on lathe using Mach3turn, G32, G76
- THC function (integrated and external controller support)
- THC advanced options (kerf detect, THC lock, low pass filter...) – **NEW**

Not supported

- Backlash compensation

Other functions

With softlimits, slow zones are not adjustable, but width of these zones is automatically determined so that given criteria for maximum motor velocity and acceleration are obeyed for every axis separately.

Technical specifications

Function	Description
Number of axes	6
Number of digital outputs	16
Number of digital inputs	14
Maximum STEP signal frequency	250 kHz (optional 125 kHz)
STEP pulse width	2 μ s
PWM output frequency	10 Hz – 200 kHz *
PWM duty cycle resolution	16-9 bits, depending on frequency; 16 bit for $f \leq 2$ kHz
Frequency of signal on Index input	≤ 10 kHz
Pulse width on Index input	≥ 100 ns
MPG/encoder input (x4) frequency	≤ 10 k steps/sec
Digital input/output type	TTL, 5 V, Pull-up resistors 4.7 k Ω on all inputs
Maximum current on digital outputs	32 mA
Number of analog inputs	1
Analog input range	0 – 3.3 V (0 – 5 V via IO card)
Charge pump outputs	2
Charge pump frequency	12.5 kHz or 5 kHz
Communication with PC	USB - data buffer about 1 s for stable communication
Power supply	from USB port
External power supply (optional)	8 – 24 VDC / 250 mA (UIO-1 card requires 15 – 20 VDC)
Dimensions	92 mm x 84 mm x 27 mm
Weight	~ 60 g

NOTE: Shown specifications are subject to change without prior notice

* PWM output signal can be assigned to the output pins 1-14

INSTALLATION

Driver installation

Connect USB motion card to a free USB port on personal computer. In most cases, if Windows 7 or newer operating system is used, Windows will automatically find and install required drivers so that manual installation should not be needed. Otherwise, if Windows does not find drivers, it will ask for location on local computer to read it from.

Drivers can be downloaded from <https://exallto.com/cnc-kontroleri/68-eth-mc-motioncontroller.html>.

Note: USB motion card does not require Mach3 LPT driver to be installed nor it uses this driver

Plugin installation

To install USB motion card Mach3 plugin, copy supplied file **usbmc_drv.dll** to Mach3 plugins folder (usually "c:\mach3\plugins"). Then, start Mach3 and new plugin should be detected (figure 2). Now choose **USB-MC-plugin** in displayed list of options. Also, optionally turn on option **Don't ask me this again** so that this choice is remembered and not displayed again on next Mach3 startup.

In case that this dialog for plugin selection is not shown, it is possible to initiate it using menu option **Function Cfg's\Reset Device Sel...**

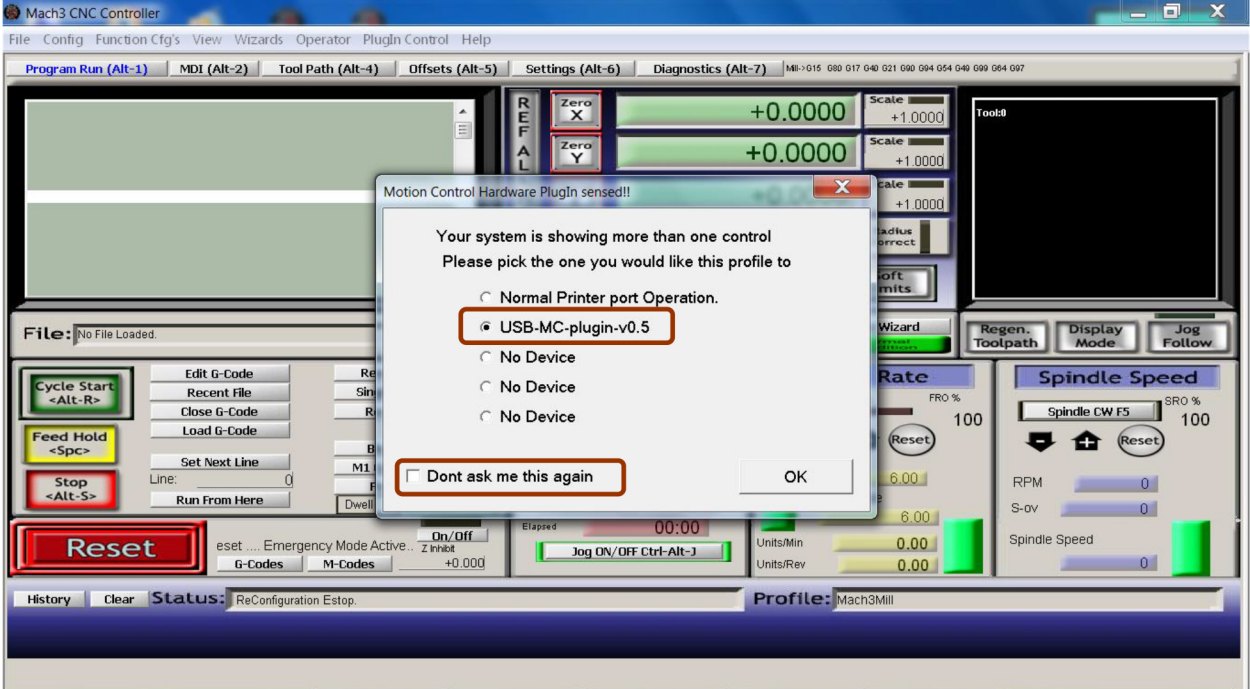


Figure 2 Plugin selection



Figure 3

On power-up, controller is in safe mode, that is, all outputs are in high impedance state (unconnected). Mode indicator LED on controller board is blinking slowly.

After clicking **RESET** button in Mach3, connection with controller is established and status like shown on figure 3 is reported. Controller then enters normal operation mode, LED indicator on board stops blinking and lights continually.

If USB connection is lost for any reason, controller instantly enters safe mode. Then it is needed to investigate and eliminate cause of error and click **RESET** button to establish communication again. Also, controller enters safe mode on all configuration changes and also on exiting Mach3 application.

Automatic firmware update

USB motion card plugin also contains needed firmware for the controller. Thus, upon establishing connection, if it is determined that firmware update is required, message like on figure 4 will be shown. It is needed to click button **Yes** and wait for this process to be completed (figure 5). Finally, result like on figure 6 should be presented. Current versions of plugin and firmware can be found on **About** window of USB motion card configuration dialog.

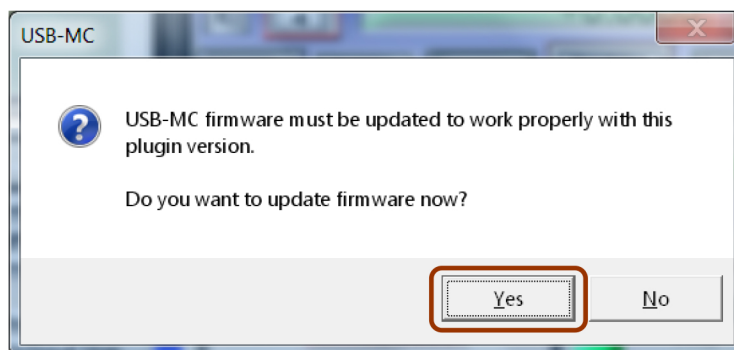


Figure 4

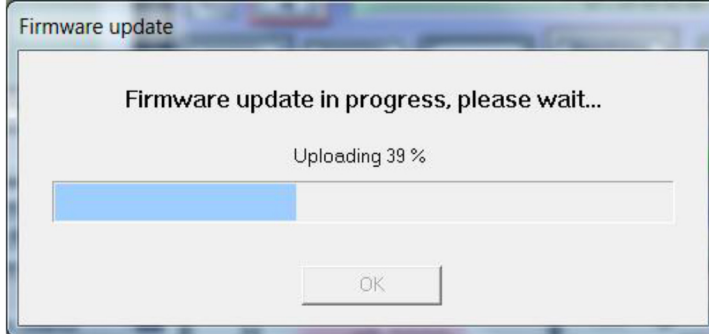


Figure 5

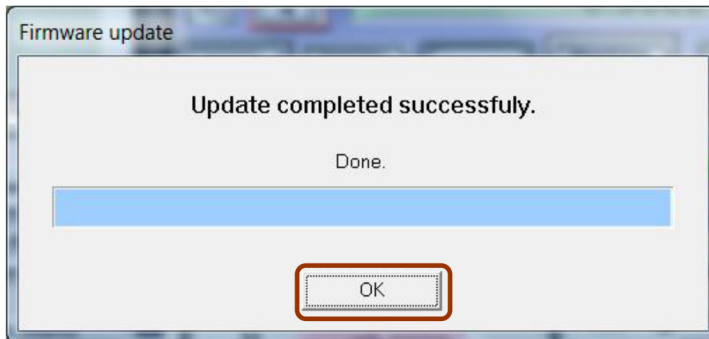


Figure 6

Configuration

Most of configuration is done using existing dialogs for adjustments in Mach3 application, like **Ports and pins**, **General config** etc. just like when LPT driver is used. Some additional options, which are offered by USB motion card, can be adjusted via dialog box that is opened using menu option **Plugin Control/USB-MC Config....** **Also, novelty is the status window that can be opened via Plugin Control/USB motion card Status...**

Adjusting ports and pins via **Ports & pins** window

USB motion card controller provides one digital input port with 14 pins and one digital output port with 16 pins. This pins can be remapped as desired, that is, can be assigned different functions that are needed for specific application.

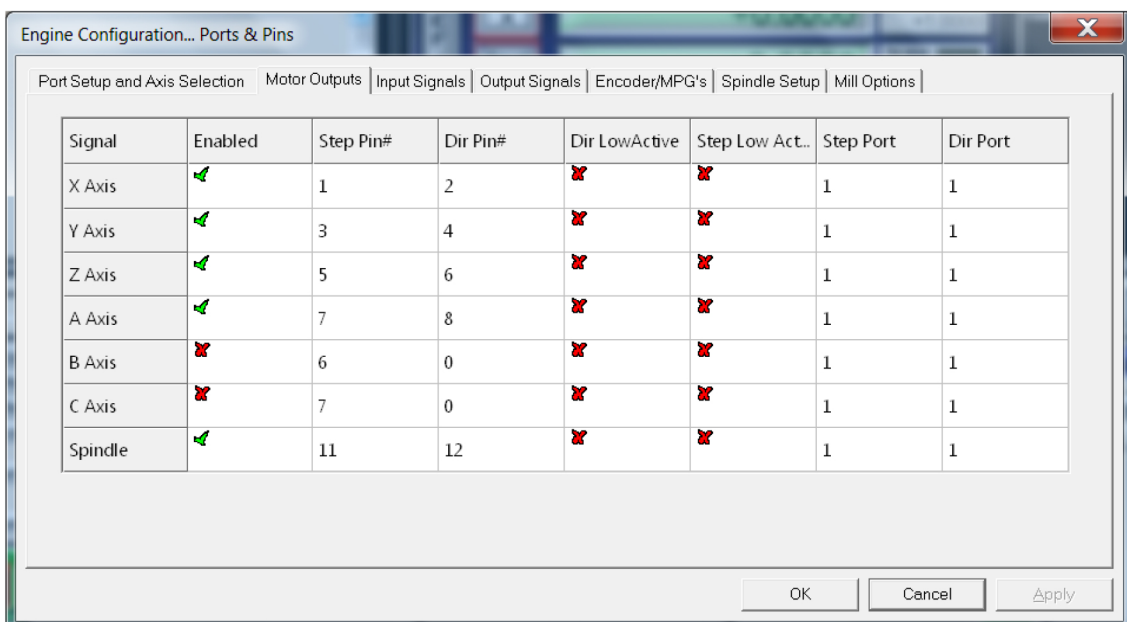


Figure 7 Ports and pins configuration

When using configuration dialogs like **Motor Outputs**, **Input Signals**, **Output Signals** etc. number 1 is always used for port number. Available pins on input port are numerated from 1 to 14. Similarly, output port pins are numerated from 1 to 16. USB motion card will ignore any port number different from 1 and any pin number that is out of available range.

When a breakout board (input/output card) is used, it is needed to refer to the card specifications for correct mapping of input and output pins.

USB motion card configuration dialog

This dialog can be opened using menu option **Plugin Control/USB-MC Config...**

General setup tab (figure 8)

Spindle/laser PWM frequency

The frequency of PWM output signal that is used for spindle rpm control or for laser power control, can be adjusted in range 10-200000 Hz. Output pin for this purpose is selected via **Spindle axis** line in **Motor Outputs** window (figure 7). Only adjustments for **Step** signal are used (**pin/low act/port**), and **Dir** field is not used for PWM output.

IMPORTANT NOTE: Only output pins 1-14 can be used for PWM output (and not pins 15 and 16).

Also, in **Ports&pins/Spindle setup** window, in **Motor control** group, options **Use spindle motor** and **PWM control** should be turned on. **PWMBase Freq** in the same group, is not used.

Home retract speed

This is speed of retraction from a home switch given as a percentage of homing speed. In first phase of homing (referencing) operation for an axis, movement toward home switch is performed until the switch is activated.

Then, movement is performed in the opposite direction (retracting) until the switch deactivates and that position is used as a reference. Home retract speed should be low enough so that good referencing precision is achieved.

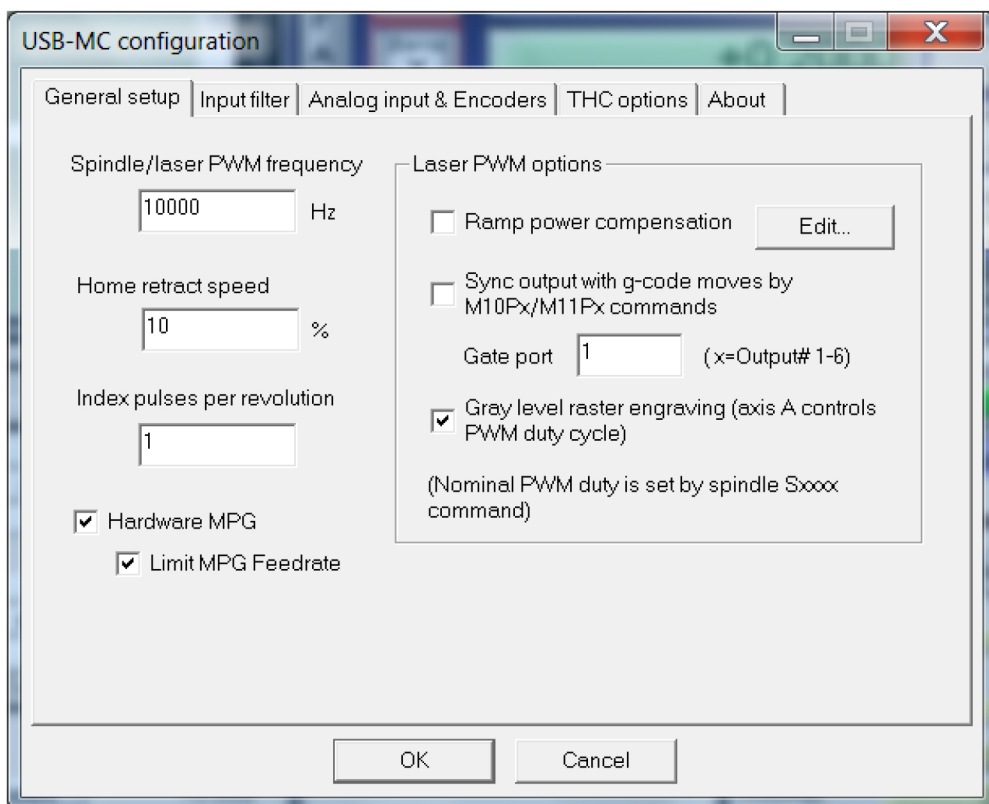


Figure 8 General setup

Index pulses per revolution

Index input is used for detection of spindle rotational speed. It is common to use one pulse per revolution, but more than one can also be used.

Laser PWM options

Ramp power compensation

Laser power compensation is used to overcome typical problem during laser engraving, and that is that depth/intensity of engraving depends on movement speed of the laser head. This is particularly visible on start and at the end of one engraving segment, where laser head slows down and stops, so unwanted black dots appear. To eliminate this phenomenon, laser power can be controlled using PWM so that PWM duty cycle is directly dependent on velocity of laser head. Thus, for example, if velocity is zero, PWM duty cycle will also be zero. As velocity increases, also is increased duty cycle that controls laser power. It is possible to configure an arbitrary relation curve.

Sync output with g-code moves, M10px, M11px

This option enables that fast commands M10px and M11px, in addition to their primary function of setting state on output x (Output#1-6), at the same time can turn on/off PWM output. **Gate port** determines which output x controls PWM output in this way. So, for example, if command M11p3 is given and **gate port=3**, PWM output will be turned on.

Laser engraving requires much faster turn on/off of laser then it is possible to achieve using spindle commands (M3, M4, and M5). By using M10/M11 commands, laser turn on/off is also ideally synchronized with g-code execution. This is done in following way: when, for example, command M11p1 (turn on output 1) is executed in g-code program, initially nothing happens, but this "turn on output x" command is remembered as armed for execution. When next command for positioning (like G01 probably at the very next program line) is executed, then at the same moment when commanded movement begins, also given output is activated. The same logic applies for M11px (turn of output) command.

Gray level raster engraving

This option is used for laser engraving of raster images and 8-bit pallet is supported (256 shades of gray). When this option is turned on A axis is used to control laser power i.e. given "movement" of A axis directly is translated to duty cycle of PWM output.

G-code should be generated from a bitmap image using one of the programs for that purpose. More details about this option and required settings in Mach3 for raster image engraving can be found in the separate document (USB motion card laser raster engraving).

Hardware MPG

If this option is turned on USB motion card will use hardware MPG mode, that is, reading MPG inputs and generation of STEP/DIR output signals is done completely in hardware without need for communication with PC. This enables very fast response (low latency) and at the same time precise motor control. Configured motor parameters (maximum velocity, acceleration) are obeyed.

If this option is turned off, standard Mach3 modes are used for MPG operation. These options can be shown by pressing TAB key in Mach3. In this case USB motion card reads MPG input, sends current position to Mach3, and Mach3 then, according to selected MPG mode (Velocity only, Multi-Step...), generates appropriate commands for movements. These commands are then sent to USB motion card and executed.

In hardware mode just like in standard modes, **CycleJogStep** is used for setting movement step, and also most of all settings (MPG axis, detent...) are common.

Limit MPG feedrate

If this option is turned on, speed limit given with parameter **MPG Feedrate** is obeyed in hardware MPG mode. This parameter is located on MPG/Jog window (figure 11).

Input Filter tab

Digital filtering (debouncing) is available for all inputs. **Input filter** window enables detailed debouncing adjustments. Debouncing time is specified in increments of 100 μ S. For example, if value 30 is given, that means that 3ms of stable state is needed on input for state to change from active to inactive or vice versa. If debounce time of 0 is given for an input, debouncing is turned off for that input. This is recommended in case we want maximum reading speed and we are sure that signal is clean (e.g. optical encoder). Debounce time can be adjusted for group of pins by function or for every pin separately (figure 9).

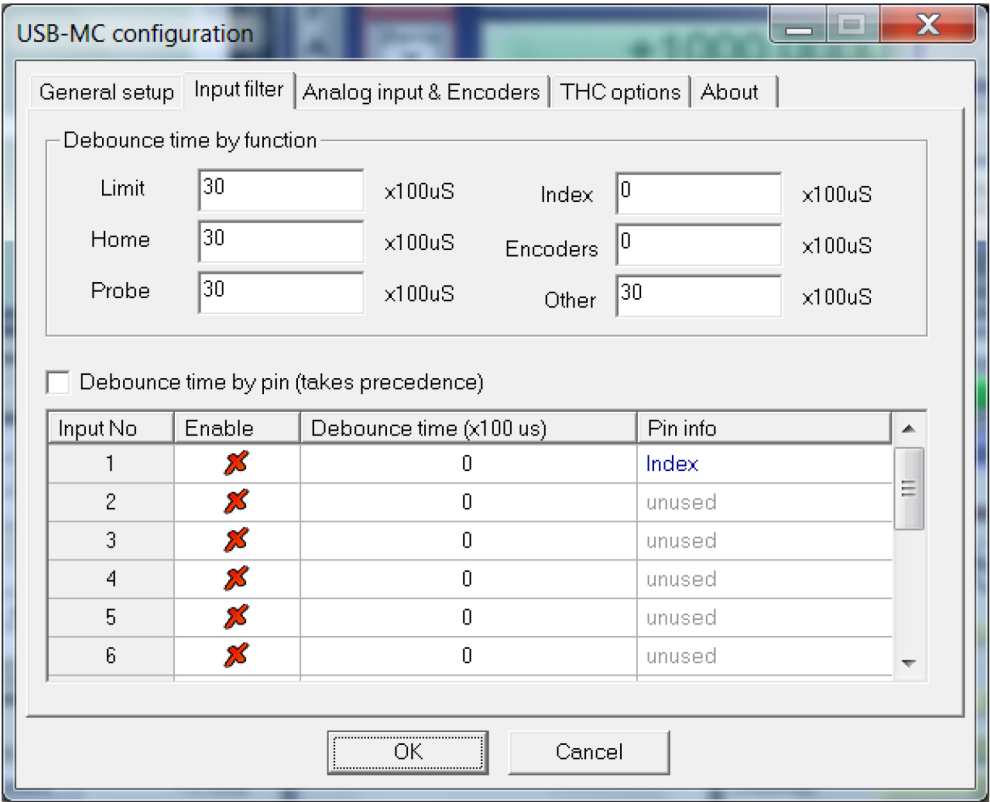


Figure 9 Input filter

Analog input & Encoders tab

USB motion card controller offers one analog input, and in addition, enables simultaneous reading of two incremental encoders. Their functionality can be adjusted using this dialog (figure 10).

Special function group

In the field on the left, available input signal sources are shown and in parentheses assigned function (if there is one). For the selected signal source, on the right side are shown parameters that can be adjusted.

For **Special function**, available options are:

- **None** – signal is not used for any special function,
- **FRO 0–250%** - feedrate override control,
- **SRO 0–250%** - spindle rate override control,

- **Set user variable** – read value is put in Mach3 internal variable so that it can be used for example from macro script or similar. **ID** represents identifier (address) of the variable. Type of output can be chosen to be 16-bit value (0–65535) or percentage (0-100%). Values of these variables can be monitored using Mach3 function **Operator/GCode Var Monitor**
- **Set user DRO** – similar to previous option, only in this case **ID** represents DRO field indicator.

When encoder is used, step increment for a variable is adjusted by setting detent value for the encoder used (see description in further text).

Zero threshold voltage

Voltage threshold adjustment for analog input, given in mV. Read value that is less or equal to this is considered to be zero.

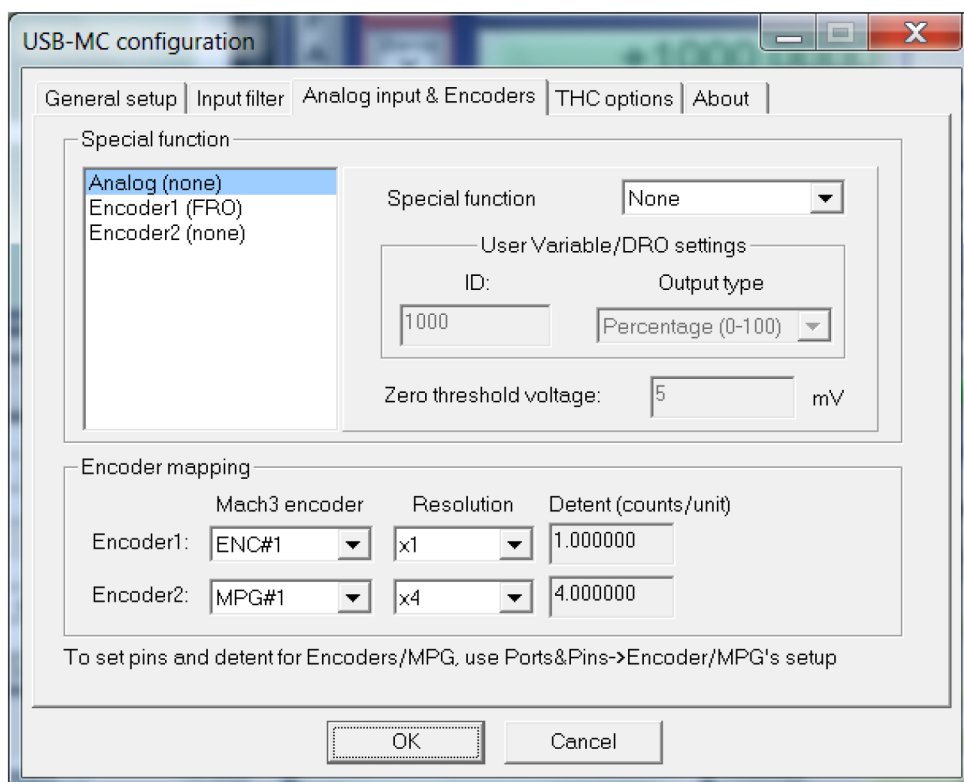


Figure 10 Analog input & encoders

Encoder mapping

USB motion card supports simultaneous reading of two incremental encoders (including one from MPG device). Since Mach3 offers adjustments for total of seven encoder inputs, it is needed to map these two encoders to desired positions.

Encoder/MPG resolution

It is used to adjust incremental encoder resolution. Available options are x1 and x4. Option x4 off course gives best resolution and is appropriate e.g. for optical encoders. Option x1 gives basic encoder resolution, that is, one increment for one full cycle of state change on A and B lines. This option is appropriate for e.g. little mechanical, rotational encoders, for which we want for one detent to correspond to position change of 1 and not 4. Also, with mechanical encoders, there is possible effect of contacts bouncing which induces errors in position reading thus it is needed to set debouncing for encoder to an optimal value. The algorithm that is used for x1 reading option is fairly resistant to these problems so it is possible to set debouncing to zero when this option is used.

Detent (counts/unit)

Detent is number of pulses (increments) from encoder/MPG for one full movement step in Mach3. For MPG, this step is defined on MPG/Jog screen (figure 11).

Detent value is, for better clarity, shown on this dialog, but can be adjusted via Mach3 window **Config/Ports&Pins/Encoders/MPG's** together with input ports and pins for encoders.



Figure 11

Detent does not have to be a whole number, and also can be negative if it is needed to change direction of rotation. Usually MPG is set to have detent value of 4 if encoder resolution x4 is chosen.

Shuttle mode

It is possible to use MPG also for Mach3 **shuttle mode**, that is, fine real-time control of execution speed of G-Code program. This function is performed completely in hardware and in this mode speed of turning MPG directly affects G-Code program execution speed.

Shuttle mode button can also be used as fast FeedHold, even if MPG is not connected or configured in the system. In this case, if shuttle mode is activated during G-code execution, movement on all axes slows down to complete stop. By deactivating shuttle mode, movement on all axes is accelerated to reach the normal speed. This acceleration/deceleration can be adjusted using field **Shuttle Accel.** which can be found on Mach3 **General Config** dialog.

THC options tab

THC (torch height control) function is used with plasma cutters for continuous regulation of plasma head vertical position above the material. In addition to support for external regulators, USB motion card motion controller also contains internal THC regulator that is possible to utilize by connecting appropriate voltage sensor to the analog input of the USB motion card. More details about THC operation and Mach3 adjustments related to this mode can be found in the [separate document \(USB-MC THC operation\)](#).

Status window

Status window (figure 12) displays current state of all input and output pins on USB motion card. Also, on the left side, current position of all 6 axes is shown, and on the right side, various status information for the controller.

This window is floating above other windows and does not prevent normal usage of Mach3 controls.

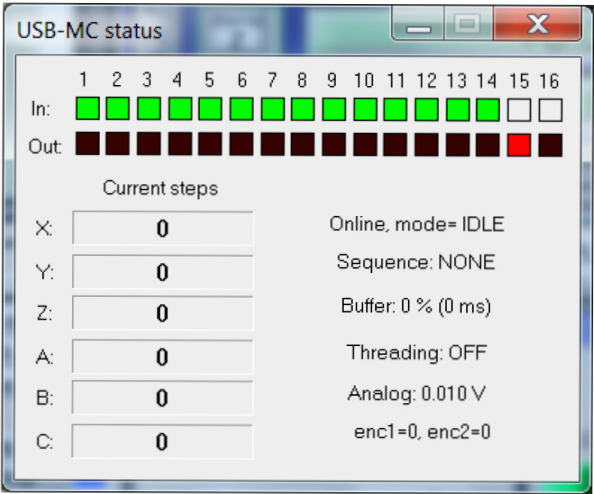
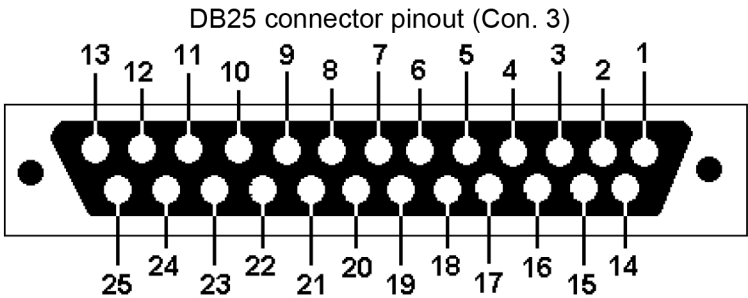


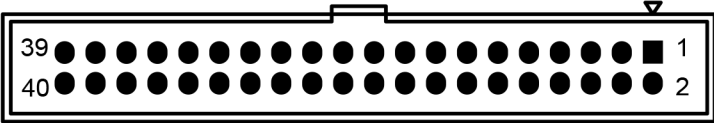
Figure 12 USB motion card status window

Connector pinouts



Pin	Function	Pin	Function
1	Out 9	14	Out 10
2	Out 1	15	In 5
3	Out 2	16	Out 11
4	Out 3	17	Out 12
5	Out 4	18	GND
6	Out 5	19	GND
7	Out 6	20	GND
8	Out 7	21	GND
9	Out 8	22	GND
10	In 1	23	GND
11	In 2	24	GND
12	In 3	25	GND
13	In 4	-	-

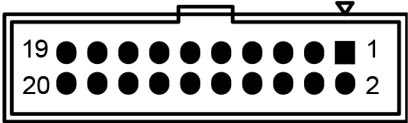
Con. 2



Pin	Function
1	Out 9
2	GND
3	Out 1
4	GND
5	Out 2
6	GND
7	Out 3
8	GND
9	Out 4
10	GND
11	Out 5
12	GND
13	Out 6
14	GND
15	Out 7
16	GND
17	Out 8
18	GND
19	In 1
20	GND

Pin	Function
21	In 2
22	GND
23	In 3
24	GND
25	In 4
26	Out 11
27	Out 10
28	In 5
29	-
30	-
31	-
32	-
33	-
34	-
35	-
36	Out 12
37	-
38	-
39	+5V
40	+5V

Con. 4



Pin	Function
1	In 7
2	In 8
3	In 9
4	In 10
5	In 11
6	In 12
7	In 13
8	In 14
9	In 6
10	Analog in
11	-
12	-
13	+3.3V
14	GND
15	+Vd
16	+5V
17	Out 13
18	Out 14
19	Out 15
20	Out 16

All digital inputs are of Schmitt trigger type which significantly reduces the susceptibility to noise and interference.

LED indicators

Status LED

Does not light up	Controller is not powered
Blinking slow	Controller is in safe mode (outputs are in high impedance state)
Constantly lights	Established connection with computer, controller is in idle mode (ready for work)
Blinking fast	A command (jog, G-code) is currently being executed
1 short blink	An error is detected (e.g. limit switch activated, ESTOP or similar). For error type look at Mach3 status line

Comm LED

Lights when there is a communication with computer.

Safety recommendations

- It is highly recommended to enforce galvanic isolation between work environment and PC (using opto-isolators and similar).
- All drives for stepper and DC servo motors have built-in opto-couplers on STEP and DIR inputs thus for these lines additional isolation is not needed. For other inputs and outputs, and depending on used equipment, it may be needed to use additional opto-isolators.
- Usage of USB motion card requires knowledge and understanding of operation of complete work system, also awareness of possible risks of working with machines and tools.
- It is advisable to place USB motion card in metal enclosure so that it is protected from external influences in presence of strong electromagnetic field, very high temperature, moisture, and similar.
- It is necessary to comply with safety standards like installation of EStop button, limit switches and similar.

DOCUMENT REVISION:

- Ver. 1.0 August 2016., Initial version
- Ver. 1.1 October 2017., Add support for laser gray scale (8-bit) engraving and support for THC control
- Ver. 2.0, March 2019., Redesigned hardware version. Digital inputs are now realized with Schmitt trigger input circuits.

